SIMULATION OF PEANUT PLANT GROWTH AND THE EFFECT OF DEFOLIATION ON GROWTH AND YIELD

By

Gail G. Wilkerson

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1980

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to Dr. S. L. Poe for serving as chairman of my supervisory committee during the major portion of my graduate program, and for providing aid and advice when needed. I also thank Dr. S. H. Kerr for assuming the role of supervisory chairman upon Dr. Poe's departure from the University of Florida, and for providing editorial assistance in the preparation of this manuscript.

To Dr. J. W. Jones I extend my sincere thanks for his invaluable assistance in all phases of this research. I would also like to thank Dr. K. J. Boote for his help in designing the field experiments, and Drs. T. R. Ashley and R. C. Littell for their advice, encouragement, and manuscript review. My appreciation also is extended to Dr. C. S. Barfield for reviewing the manuscript.

I especially want to thank Dr. W. G. Duncan for so kindly allowing me to use his PENUTZ model and for discussing it with me.

To John Mangold, Carol Lippincott, Randy Stout, and Gail Childs I express my heartfelt thanks for their help with the field work, for without their assistance this research would not have been possible.

I wish to thank Mary Jermann for her help in typing the final copy of this dissertation, and I especially want to thank Barbara Lemont for her excellent work on the graphs contained in this dissertation.

Above all, I thank my son, Trevor, for putting up with a grouchy mom on many occasions.

TABLE OF CONTENTS

CHAPTER		PAGE
	ACKNOWLEDGEMENTS	ii
	LIST OF TABLES	v
	LIST OF FIGURES	viii
	ABSTRACT	x
I	INTRODUCTION	1
II	GROWTH OF NON-DEFOLIATED PEANUT PLANTS	6
	Introduction	6
	Effect of Temperature on Plant Growth	8
	Photosynthesis	8
	Methods and Materials	10
	Crop Management	10
	First Experiment	11
	Second Experiment	13
	Results	14
	First Experiment	14
	Second Experiment	17
III	THE EFFECTS OF DEFOLIATION ON PEANUT PLANT GROWTH	29
	Introduction	29
	Methods and Materials	35
	First Defoliation	35
	Second Defoliation	37
	Third Defoliation	38
	Fourth Defoliation	38
	Results	39
	First Defoliation	39
	Second Defoliation	44
	Third Defoliation	48
	Fourth Defoliation	52
IV	THE SIMULATION MODEL	57
	Introduction	57
	Description of the Model	60
	Initiation of New Leaves and Branches	64
	Calculation of the Day's Net Photosynthate	66

CHAPTER PAGE

Calculation of Increases in Total Dry Weight per Unit of Carbohydrate. 72
Inactivation of Vegetative Growing Points. 73
Cessation of Peg and Pod Initiation. 74
INSECT Subroutine. 75
Subroutine ATTAC 77
Results and Discussion 79
Comparison of Model Predictions with Growth of Non-defoliated Plants in the Field. 79
Comparison of Model Predictions with Results of the Field Defoliations. 90
Simulation of Insect Cohort Entering the Field . . . 110

V SUMMARY AND CONCLUSIONS. 115

APPENDICES

1 WEATHER DATA FOR THE 1978 GROWING SEASON 118

2 FLOW CHARTS OF THE MAJOR SUBROUTINES IN PMINUS 123

3 COMPUTER PRINTOUT OF PMINUS. 151

4 DESCRIPTION OF MODEL PARAMETERS. 193

5 INPUT PARAMETERS AND VARIABLES DESCRIBING DYNAMICS OF PEANUT PLANT GROWTH. 198

REFERENCES CITED 206

BIOGRAPHICAL SKETCH. 210

LIST OF TABLES

TABLE		PAGE
1	Average leaf growth for 4 Florunner peanut plants marked weekly and harvested at 16 weeks.	15
2	Average numbers and weights of pods of various size categories from 4 Florunner peanut plants marked on a weekly basis during 1978 and harvested at 16 weeks of age.	16
3	Average leaf growth for Florunner peanut plants during the 1978 growing season, as indicated by weekly plant samples	18
4	Average stem growth for Florunner peanut plants during the 1978 growing season, as indicated by weekly plant samples	19
5	Average numbers and weights of pods present on the Florunner peanut plants harvested each week during the 1978 growing season.	20
6	Number of new leaves per branch during the 1978 growing season, as indicated by weekly plant samples.	21
7	Estimation of leaf loss by Florunner peanut plants during the 1978 season, as indicated by weekly plant samples.	22
8	Comparison of specific leaf weights for leaves initiated at the same time but harvested within a week or at week 16.	24
9	Results of linear correlations of stem size to plant age and plant size for Florunner peanuts. . . .	26
10	Average size of stem internodes during the 1978 season, as indicated by weekly plant samples.	27
11	Summary of the defoliation experiments performed during the 1978 growing season on Florunner peanut plants.	40

TABLE		PAGE

12	The effect of various levels of defoliation at $4\frac{1}{2}$ weeks upon plant size at 7 weeks.	41
13	Estimated leaf and stem gains in the $2\frac{1}{2}$ weeks following defoliation at $4\frac{1}{2}$ weeks.	43
14	Summary of light interception by plants 7 weeks of age which had been defoliated at $4\frac{1}{2}$ weeks.	45
15	The effect of 50% defoliation at week 9 upon plant size at week 11.	46
16	The effect of 50% defoliation at week 9 upon plant size at week 15.	47
17	Summary of light interception by plants defoliated at 9 weeks of age.	49
18	The effect of 50% defoliation at week 12 upon plant size at 14 weeks.	50
19	The effect of 50% defoliation at week 12 upon plant size at week 16.	51
20	Summary of light interception by plants defoliated at week 12.	53
21	The effect of defoliation at 16 weeks upon plant size at 18 weeks.	54
22	Summary of light interception by plants defoliated at 16 weeks.	56
23	A brief description of the user-written subroutines included in PMINUS.	61
24	Root growth during the 1978 growing season, as indicated by weekly plant samples.	69
25	Comparison of leaf growth in the field with model predictions.	89
26	Comparison of model predictions with field results for plants defoliated at $4\frac{1}{2}$ weeks and harvested at 7 weeks.	91
27	Comparison of model predictions with field results for plants defoliated at 9 weeks and harvested at 11 weeks.	94

TABLE		PAGE
28	Comparison of model predictions with field results for plants defoliated at 9 weeks and harvested at 15 weeks.	95
29	Comparison of model predictions with field results for plants defoliated at 9 weeks and harvested at 14 weeks.	98
30	Comparison of model predictions with field results for plants defoliated at 12 weeks and harvested at 16 weeks.	99
31	Specific leaf weights and average size of new leaves grown in the 2 weeks following defoliation.	104
32	Comparison of model predictions with field results for plants defoliated at 16 weeks and harvested at 18 weeks.	106
33	Comparison of simulated and experimental (Mangold, 1979) growth of Florunner peanuts in the 2 weeks immediately following defoliation at 8 weeks.	108
34	Comparison of simulated and experimental (Mangold, 1979) yields for Florunner peanuts defoliated at various points in the season.	109

LIST OF FIGURES

FIGURE		PAGE
1	Relationship between leaf area index and percent light interception for Florunner peanuts planted on 24 May 1978.	28
2	Simulated and experimental leaf area index for Florunner peanuts planted on 24 May 1978.	80
3	Simulated and experimental change in leaf numbers for Florunner peanuts planted on 24 May 1978.	81
4	Simulated and experimental leaf growth for Florunner peanuts planted on 24 May 1978.	82
5	Simulated and experimental stem growth for Florunner peanuts planted on 24 May 1978.	83
6	Simulated and experimental changes in pod numbers for Florunner peanuts planted on 24 May 1978.	84
7	Simulated and experimental pod growth for Florunner peanuts planted on 24 May 1978.	85
8	Simulated and experimental change in number of fully expanded pods for Florunner peanuts planted on 24 May 1978.	86
9	Simulated and experimental growth of fruit filling seeds for Florunner peanuts planted on 24 May 1978. .	87
10	The simulated and experimental effect of 50% uniform defoliation at 9 weeks after planting on LAI (a) and pod dry weight (b).	96
11	The simulated and experimental effect of removal of all leaves from the outer 50% of the canopy at 9 weeks after planting on LAI (a) and pod dry weight (b).	97
12	The simulated and experimental effect of 50% uniform defoliation at 12 weeks after planting on LAI (a) and pod dry weight (b).	100

FIGURE		PAGE

13 The simulated and experimental effect of removal of all leaves from the outer 50% of the canopy at 12 weeks after planting on LAI (a) and pod dry weight (b). 101

14 The simulated and experimental effect of 50% uniform and 100% defoliation at 16 weeks after planting on LAI (a) and pod dry weight (b). 107

15 The simulated effect of 10 larvae/plant entering the field on day 35 after planting and feeding for 26 days at an increasing rate. 111

16 The simulated effect on LAI (a) and pod dry weight (b) of 10 larvae/plant entering the field on day 56 and feeding for 26 days at an increasing rate. 113

17 The simulated effect on LAI (a) and pod dry weight (b) of 20 larvae/plant entering the field on day 35 and feeding for 26 days at an increasing rate. 114

Abstract of Dissertation Presented to the Graduate Council of the University of Florida in Partial Fullfillment of the Requirements for the Degree of Doctor of Philosophy

SIMULATION OF PEANUT PLANT GROWTH AND THE EFFECT OF DEFOLIATION ON GROWTH AND YIELD

By

Gail G. Wilkerson

June 1980

Chairman: S.H. Kerr
Major Department: Entomology

Field experiments were performed to produce information necessary for modification and expansion of an existing peanut plant growth model so that the effects of insect defoliation could be simulated. In order to provide a baseline for normal growth, several plants were selected at the beginning of the season and their growth followed until the end of the season. In addition, plants were harvested weekly. Plants were defoliated mechanically at 4½, 9, 12, and 16 weeks after planting and were harvested 2, 4, or 6 weeks following treatment.

Early season defoliations (at 4½ weeks) resulted in reductions in weights of all plant parts; whereas later defoliations resulted in significantly lower stem weight to length ratios, lower pod numbers and weights, and equal or higher leaf numbers and weights. Apparently

this peanut cultivar (Florunner) accumulates reserves in the stem during the course of the season which can be utilized to grow new leaves or to fill pods in the event of defoliation.

PMINUS is the simulation model developed on the basis of these experiments. Plant growth depends upon physiological time and intercepted radiation. The model keeps track of the number and weight of leaves, internodes, and pods initiated each day. New vegetative and reproductive branches are initiated according to the branching pattern of the plant. Light interception (calculated on the basis of leaf area index) is used to determine amount of photosynthesis each day. Carbohydrate supply and demand are balanced each day based on a system of priorities which changes during the course of the season. The model successfully describes the growth of both defoliated and nondefoliated plants. PMINUS is designed so that it can be easily coupled to either a plant disease or an insect development model, as is demonstrated by the introduction of a theoretical insect population.

CHAPTER I
INTRODUCTION

Peanuts are an important food and oil crop. During the period 1967-1969, an average of nearly 45 million acres of peanuts was grown annually throughout the world and over 1.4 million acres were grown in the United States (McGill, 1973). The peanut agroecosystem is complex, in that there are numerous arthropods, weeds, and diseases which attack peanut plants and affect crop growth and yield. In addition, growth and yield are influenced by soil and weather conditions, and by crop management practices. The effects of many of these factors are dynamic--for example, final yield may be less affected by a given level of moisture stress or defoliation at one time in the season than at another. Furthermore, there is interaction between factors; a plant that has been weakened by disease may be less able to withstand insect defoliation. Linker (1980), working in north Florida, noted an interaction between a crop management practice (date of planting) and numbers of fall armyworm, *Spodoptera frugiperda* (J.E. Smith), and corn earworm, *Heliothis zea* Boddie, larvae obtained in his field samples. As a result of this interaction, in 1975 and 1976 the later in the season the crop was planted, the more insecticide treatments were required for crop protection.

Given the dynamic nature of the different factors involved in determination of final yield, and the difficulty of designing and

performing experiments to directly determine the effects of interactions between the various factors, modeling and computer simulation can be effectively used in pest management programs for studying crop management decisions on the basis of overall costs and gains. In addition, the modeling approach can be used to evaluate various hypotheses of how particular processes in pest management systems are controlled and function. For example, there is much about plant growth that is still not fully understood, and any model of plant growth contains many explicit or implicit assumptions about the operation of the various processes. Although simulation cannot be used to prove that a particular process operates in a certain manner, it can be used to separate hypotheses that warrant further experimentation from those that are inoperable.

The purpose of my research was to develop a computer simulation model of peanut plant growth containing the necessary mechanisms for coupling it to an insect development model. As this research was part of an interdisciplinary pest management project concerned with the effects of diseases as well as insects, a model structure of sufficient complexity to allow for the incorporation of both was needed.

There has been at least one research effort aimed at modeling the effect of foliage-consuming insects on peanut yield (Smith and Kostka 1975). These investigators fitted a response surface of yield to plant defoliation and plant phenology. This method of modeling has the disadvantage that it does not allow for interactions of the various components of the crop system which account for the final yield, and was therefore unsuitable for the purposes of this study. There were 2 peanut plant growth models available for consideration: that developed by Young et al. (1979) and that developed by Duncan (1974). There were

problems involved with using either of these models for simulation of insect and disease damage. PENUTZ, the model developed by Duncan (1974), does not include leaf and stem components explicitly, only as vegetative top weight. Photosynthesis each day is based on percent ground cover which is calculated by considering the plant canopy as expanding circles which eventually overlap and achieve 100% ground cover. The rate of expansion is determined by temperature (Duncan et al. 1978). Insects eat leaves and the translation of feeding into changes in canopy geometry would be difficult, if not impossible. Duncan's model therefore could not be used without modification.

The model developed by Young et al. (1979) does separate leaf from stem mass and it does store the amount of leaf mass added each day so that leaf material of a given age can be removed from the system. This ability to separate plant material by age is important for simulation of either insect or disease damage. For this reason, the model of Young and his co-workers would have been used if it had not had one serious disadvantage. The model requires values for a large number of empirical parameters. In order to find values for these parameters, Young et al. fitted data for 9 planting dates each year. In many cases a parameter value changed radically from one year to the next. There were insufficient data available for determination of realistic values of these parameters for Florida growing conditions in 1978. Duncan's model was developed largely from data obtained in Gainesville, Florida, and I therefore anticipated fewer problems in fitting growth of my non-defoliated plants to his model. Thus a decision was made to modify his model for this study.

Of the 3 general approaches for partitioning growth into crop components discussed by Jones and Smerage (1978), the morphogenetic approach seemed the most applicable for the purposes of this study. In this view of growth, individual plant organs (such as leaves and pods) are initiated and grow for a finite time. Potential growth rates of individual organs are calculated, sink demand is calculated for each crop component, and growth is limited by substrate availability. A tobacco model (Hackett 1972) and several cotton models (Stapleton and Meyers 1971, McKinion et al. 1975, and Jones et al. 1980) have used the morphogenetic approach to partitioning.

Duncan's PENUTZ model is based on the philosophy that the peanut plant partitions a certain amount of the available photosynthate to the reproductive portion of the plant and that this amount varies with cultivar. Since it calculates pod demand each day, it was only necessary to add the initiation of vegetative organs and the calculation of vegetative demands each day to develop the morphogenetic model, PMINUS, from PENUTZ. As there were insufficient data available in the literature to do this, experiments were designed to provide information on initiation and rate of growth of leaves and branches and the weight and area of individual leaves throughout the season on plants without insect damage. The development of stems, roots, and pods was also followed in these experiments so that model predictions of plant growth could be verified. Since Florunner is the most commonly grown cultivar in the United States (Duncan et al. 1978), it was used in all experiments. These experiments dealing with the normal growth of non-defoliated plants are discussed in Chapter II.

There were some indications in the literature that defoliation might have a more complex effect on peanut plant growth than simply reducing leaf area, light interception, and therefore photosynthesis. Experiments were designed to investigate the effect of different kinds and levels of mechanical defoliation upon plant growth--in particular upon the plant branching pattern and the partitioning of available photosynthate into the various plant organs. These experiments are discussed in Chapter III.

A computer simulation model was developed, using the results of the experiments discussed in Chapters II and III, information contained in the literature, and portions of PENUTZ. As there were many elements of peanut plant growth for which there was no information available for determination of model structure and parameters, various hypotheses were tested until a model structure and parameters were developed which successfully described growth of both defoliated and non-defoliated plants. Defoliation experiments performed by Mangold (1979) were then simulated to partially validate the model. A theoretical insect population was introduced at various points in the growing season, at 2 population levels, to demonstrate the usefulness of the model and to investigate the importance of time and location of damage to final yield. Chapter IV deals with this simulation model.

CHAPTER II
GROWTH OF NON-DEFOLIATED PEANUT PLANTS

Introduction

The Florunner cultivar of peanuts used in this study is a prostrate member of the Virginia varietal group (Arachis hypogaea L. var. hypogaea), according to the classification system given by Gregory et al. (1951). As such, it is characterized by indeterminate growth and a branching system which consists of a central stem axis and variable numbers of lateral axes, including 2 prominent cotyledonary laterals. All branches directly off the mainstem are vegetative, and all lateral branches are vegetative in the first node and predominantly vegetative in the second node. Nodes on vegetative branches of all orders generally occur in alternating vegetative and reproductive pairs. Malagamba (1976) found that the number of primary, secondary, and tertiary branches produced by Florunner is related to planting density. In his experiments, the number of primary branches/m^2 increased linearly with increasing plant density, while number of secondary branches reached a peak at approximately 30 plants/m^2, and then declined. The number of tertiary branches decreased with increasing plant density--there being no tertiary branches at the higher densities.

In Florida, growth of Florunner typically proceeds in the following manner: plants begin to emerge ca. 5 days after planting; 100% ground cover is reached 8 to 9 weeks after planting when the LAI (leaf area

index[1]) reaches ca. 3.0; leaf area continues to climb until week 11 or 12; and stems increase in weight until week 13. Flowering starts at day 30 to 35, reaches a peak at 8 to 9 weeks, then declines to zero by week 13. Pegs[2] appear 1-2 weeks after the first flowers, reach a maximum about 6 weeks later, then decrease in number. Pegs start to swell about a week after they first appear; the number of pods increases until about week 12, when it plateaus; and seeds begin to fill around day 70. Harvest occurs between 19 and 20 weeks after planting (McGraw 1977, McCloud 1974, Duncan et al. 1978).

The time required to reach 100% ground cover varies with planting density, as do the maximum LAI achieved and the number of pegs and pods per plant (Malagamba 1976). Final yield per unit ground area is much less affected by density, however, Cahaner and Ashri (1974), working with 4 Virginia-type varieties, found equal yields of mature pods for the 3 planting densities investigated. Malagamba (1976) found a fast increase in yield was obtained, then a slow decline phase starting at 20 to 22.5 plants/m^2.

Many flowers bloom and fail to produce pegs and many pegs fail to develop into mature pods. Smith (1954), investigating reproductive efficiency in a Virginia Runner variety, found 93.3% of the egg cells in all ovules were fertilized but only 63.5% actually elongated as pegs. Of the pegs which did elongate, only one-third reached the stage of pod enlargement, and a third of these pods failed to reach maturity. Only

---

[1]Leaf area index is the ratio of leaf area to ground area.

[2]The ovary elongates as a peg and enters the ground before enlargement of the pod commences.

11.4% of the ovules present at anthesis became seeds. Smith noted that the ovaries of pollinated peanut flowers can remain dormant for several weeks without losing their ability to resume active fruit development and that flowering resumes when fruits are removed. Bolhuis (1958) found that continuous removal of flowers (thus preventing fruit development) resulted in not only a prolonged flowering period but also a greater than normal number of flowers per plant per day. Gupton et al. (1968) found that the order of pegging is related to the branching pattern of Virginia type peanuts and that the order of peg development is essentially the same as the order of peg placement.

Effect of Temperature on Plant Growth

Temperature has an important effect on peanut plant development. Bolhuis and DeGroot (1959) found that a temperature of 33°C was too high for normal development and a temperature of 21°C was too low. In their study of 3 varieties they noted that tolerance to different temperatures increased as the latitude from which the varieties originated increased. Jacobs (1951) found that vegetative and gynophore (peg) growth reacted differently to various temperature combinations. In a study of Florigiant peanut plants, Cox (1979) determined that early growth was optimum at a weighted mean temperature of 27.5°C and no growth occurred at 15.5° C. Treatments 4°C above or below the optimum 30/26°C temperature resulted in less dry weight. The optimum temperature for fruit growth (24°C) was lower than that for top growth.

Photosynthesis

In a study of 5 genotypes, including 2 cultivars of *Arachis hypogaea* L. and 3 wild species of *Arachis*, Florunner was found to have the highest

rate of photosynthesis by Bhagsari and Brown (1973). In an expanded study of 31 peanut genotypes, Bhagsari and Brown (1976) again found Florunner to have the highest photosynthetic rates. Pallas and Samish (1974) also found Florunner to have one of the highest rates of photosynthesis of the extensively cultivated varieties. Even though their plants were grown at low light intensity, they did not photosaturate at the highest light intensity tested, which was slightly less than full sunlight.

Pallas and Samish (1974) noted that the photosynthetic rate of an individual peanut leaf dropped after it was 3 or 4 weeks of age. Henning et al. (1979) obtained similar results, with younger leaves exhibiting higher apparent photosynthetic (AP) rates. In addition, they noted that the mean AP rate decreased in a nearly linear fashion with increasing plant age from 80 to 140 days. Trachtenberg (1976) found that leaf net photosynthetic rates increase with leaf age until peanut leaves are less than 2 weeks old, then decline with leaf age. The P_{max} (theoretical maximum photosynthesis) for individual peanut leaves in his experiment was calculated at 77 mg CO_2 dm^{-2} hr^{-1} and the P_{max} for leaves over 6 weeks old was 43.5 mg CO_2 dm^{-2} hr^{-1}.

Gautreau (1973) found that differences in climatic factors greatly affected the growth of all plant parts. He felt that differences in light intensity were particularly responsible for differences in length of stem internodes and of the mainstem and other branches. Cox (1978) determined that mainstems were quite elongated under low light treatments and the number of flowers was markedly reduced. Hang An (1978) found that shading affected flowering, pegging, and size of fruit load.

Yield was most reduced by shading during the pod filling period (83 to 104 days after planting).

The experiments discussed in this chapter were designed to provide basic information on normal peanut plant growth, necessary for modification of PENUTZ. In the first experiment the growth of several plants was followed throughout the course of the season to give a unified view of addition and loss of leaves, addition of vegetative branches, and development of pods of a known age. The second experiment was planned to furnish weekly estimates of LAI, the number of new leaves/branch, the weight, specific leaf weight, and area of new leaves, the size of stem internodes, and changes in weight of other plant parts. Plant maps were made so that the time and order of initiation of vegetative and reproductive branches could be determined. Light interception was measured periodically throughout the season and was correlated to LAI. The calculation of photosynthesis each day in the model could then be based upon LAI, rather than canopy geometry, as it was in PENUTZ.

Methods and Materials

Crop Management

Florunner peanuts were hand planted 2 per hill on 24 May 1978 at the University of Florida agronomy farm, Alachua County, Florida. The plants were thinned to 1 per hill after emergence. Rows were 76.2 cm apart and there were 13.8 cm between plants, giving a plant population of 9.5 plants per m^2. This is within the plant density range for maximum yield (Malagamba 1976).

The soil type at the site was Arredondo fine sand. The field was well-irrigated prior to planting and irrigated again briefly the day after planting. A tensiometer was installed in the field to measure soil water tension at different depths and the plot was irrigated as needed to prevent significant water stress. Rainfall and maximum and minimum temperatures were recorded daily.

Rhibozium innoculum was added to the furrows at planting, and gypsum was applied by hand at the rate of 1700 kg/ha on 26 June. Weeds were controlled with preplant and cracking time herbicides. Ethylene dibromide was injected into the soil 5 days before planting for nematode control. The fungicide chlorothalonil was applied from 22 June until 22 September at 7-10 day intervals. Insecticides were applied as needed to minimize damage by foliage-feeding lepidopterous larvae. On 24 August, fensulfothion RCNB granules were hand-broadcast to slow the spread of white mold, Sclerotium rolfsii. Further details of the pesticide applications can be found in Mangold (1979).

First Experiment

For the first experiment, in which the growth of several plants was to be followed throughout the season, 7 plants were selected on 14 June, 3 weeks after planting. These plants were marked once a week until 9 August, when 2 plants were harvested. The remaining 5 were harvested on 13 September, 16 weeks after planting. The experimental plants were all surrounded by healthy plants which were left undisturbed throughout the season.

Once a week each new, fully expanded leaf on the selected plants was marked by placing a colored surgical wound clip around the petiole.

A leaf was considered fully expanded if the next leaf on the branch was starting to unfold. New vegetative branches were marked by placing a spot of acrylic paint on the axil of the leaf at the node from which the branch was emerging. Pegs that had entered the ground during the preceding week also were marked with colored surgical wound clips. The color of paint and clips was different each week so that at the end of the experiment the age of each leaf, stem, and pod could be determined. The numbers of marked pegs, leaves, and stems were recorded each week.

When the plants were brought in from the field, the location and age of leaves, stems, and pods were mapped. The leaves were separated by age and counted; leaf area was determined by use of a Lambda[3] leaf area meter; and after drying the leaves were weighed. Marked pods also were separated by age and further divided into categories of P3, P4, and P5. A P3 pod is defined as one that is slightly swollen; a P4 as one that is fully expanded but which shrinks when dried; and a P5 is one that is fully expanded which does not shrink when dried (Hang An 1976). The pods in the various categories were counted, then dried and weighed.

All plant parts in all experiments were dried at 60°C for at least 48 hr prior to weighing. Data were analyzed using the Statistical Analysis System on an Amdahl 470 V/6-11 with OS/MVS Release 3.8 and JES2/NJE Release 3. Computing was done using the facilities of the Northeast Regional Data Center of the State University System of Florida, located on the campus of the University of Florida in Gainesville.

[3]Lambda Instruments Corporation, Lincoln, NE.

Second Experiment

In this experiment 11 rows of plants were used. Sample plants were selected from rows 2, 4, 6, 8, and 10. The other rows were left undisturbed. Three weeks after planting, healthy plants which had a healthy plant on each side were selected, numbered, and marked with a flag. There were always at least 2 plants between sample plants. A random number table was used to select the plants to be harvested each week. Nine or 10 plants were harvested 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, and 20 weeks after planting. On weeks 11, 14, 15, 16, and 18 the control plants from the defoliation experiments performed in the same field were used in determination of plant growth for those weeks. Each week 3 plants were marked in a manner similar to that described in the first experiment, and the plants were harvested the following week so that number of new leaves, stems, and pods could be determined on a weekly basis. These 3 plants were mapped as to location of branches, both reproductive and vegetative, old and new leaves, and pegs and pods. Old and new leaves were counted and weighed. A 50 or 100 leaflet sample was measured for determination of specific leaf weight.

All the plants harvested each week were taken apart and leaves, P1-P5, and growing points were counted. All stems were measured and dry weights were obtained for leaves, stems, roots, vegetative growing points, reproductive branches and pegs, petioles, P3-P5, and kernels.

Beginning when the plants were 6 weeks old, canopy interception of photosynthetically active radiation (PAR) was measured periodically in the following manner: a metal track 3 cm wide with 3 cm sides was inserted perpendicular to the row between plants and a pyranometer[4]

---

[4] Lambda Instruments Corporation, Lincoln, NE.

(LI-COR 2005) was pulled by its cord manually along the track at a constant rate for 1 minute. The pyranometer was connected to a quantum-radiometer-photometer[5] (LI-COR 185) and printing integrator[5] (LI-COR 550). PAR measurements were made on days of clear skies between 900-1500 hours EST and an ambient full-sun reading above the canopy was recorded within 1-2 minutes of the canopy reading.

Results

First Experiment

One of the 5 plants which were harvested 16 weeks after planting had been attacked by white mold and thus had to be discarded. Data obtained on leaf growth are summarized in Table 1; that for pod growth in Table 2. The number of new leaves per plant per week was at a maximum during weeks 9, 10, and 11, and fell sharply after week 12. By week 16, approximately 80% of the leaves grown during the first 3 weeks following planting had been lost, but only 34% of the leaves grown between weeks 3 and 4 had been lost. Most of the leaves grown after week 5 were still present at 16 weeks. There was a sharp drop in specific leaf weight after week 5. No new vegetative branches were initiated after week 13.

Pegs first entered the ground between weeks 6 and 7, as can be seen in Table 2. Some of these earliest pods failed to mature by week 16. The greatest number of pods appeared to be added between weeks 9 and 10, although about 27% of all pods escaped marking and many of

[5]Lambda Instruments Corporation, Lincoln, NE.

Table 1. Average leaf growth for 4 Florunner peanut plants marked weekly and harvested at 16 weeks.

Week	No. Leaves Marked	No. Leaves Still Present at 16 Weeks	Leaf Area, cm^2	Specific Leaf Wt., mg/cm^2	Weight per Leaf, mg	No. New Veg. Growing Pts.
3	8.5	1.8	24.3	5.48	73.9	4.6
4	11.0	7.3	50.8	5.96	41.5	3.2
5	21.0	15.5	129.7	5.42	45.4	8.6
6	34.2	31.2	484.9	4.11	63.9	10.4
7	34.8	33.0	777.5	3.82	90.0	5.8
8	34.2	33.0	941.4	3.74	106.7	6.0
9	44.8	39.8	1220.8	3.98	122.1	5.4
10	42.8	40.8	1097.3	4.04	108.7	1.8
11	39.5	39.0	995.3	4.10	104.6	5.0
12	34.8	34.8	833.6	4.23	101.3	1.4
13	25.2	25.0	492.3	4.27	84.1	1.2
14	18.2	16.5	280.7	4.24	72.1	0.0
15	10.5	10.5	164.6	4.12	64.6	0.0
16	10.2	10.2	167.4	4.17	68.5	0.0

Table 2. Average numbers and weights of pods of various size categories from 4 Florunner peanut plants marked on a weekly basis during 1978 and harvested at 16 weeks of age.

Week Peg Entered Ground	P3 at Harvest		P4 at Harvest		P5 at Harvest		Total Pods Present at Harvest		Kernel Weight at Harvest, g
	Number	Weight, g	Number	Weight, g	Number	Weight, g	Number	Weight, g	
6-7	0.0	---	0.6	0.1	2.4	3.0	3.0	3.0	2.5
7-8	0.2	0.0	1.2	0.7	5.0	6.7	6.4	7.4	5.5
8-9	0.8	0.0	1.2	0.4	6.0	6.5	8.0	6.9	5.4
9-10	2.0	0.1	3.6	1.7	11.4	11.7	17.0	13.4	9.6
10-11	1.8	0.1	3.8	1.8	6.8	5.5	12.4	7.4	4.3
11-12	1.2	0.0	2.0	0.7	2.0	1.6	5.2	2.4	1.2
12-13	0.0	---	0.6	0.1	0.4	0.3	1.0	0.4	0.3
13-14	0.2	0.0	0.2	0.0	0.0	---	0.4	0.1	0.0
14-15	0.0	---	0.0	---	0.0	---	0.0	---	---
15-16*	6.8	0.2	2.2	0.5	11.4	12.5	20.4	13.2	10.2

*Actually pods that were not marked.

these were early pods close to the base of the plant with little or no peg visible above ground. Very few pods were added after week 12. Weather data for the growing season are summarized in Appendix 1.

Second Experiment

Leaf, stem, and pod growth are summarized in Tables 3, 4, and 5, respectively. Based on the number of new leaves and the ratio of stem weight to length, both leaf and stem growth seemed essentially to cease after week 14. As can be seen in Table 3, specific leaf weight and weight per leaf of new leaves changed rather abruptly twice during the season--between weeks 5 and 6 and again between weeks 10 and 11. Number of new leaves per active vegetative meristem also decreased between weeks 10 and 11 (Table 6). The number of active vegetative growing points was derived from a study of the plant maps made of the 3 marked plants harvested weekly. From week 9 on, some growing points were being inactivated even as new ones were being initiated closer to the exterior of the canopy. Presumably this was due to a lack of light penetration to the interior of the canopy.

No consistent pattern of leaf loss could be determined from the available data (Table 7). Even though an attempt was made to minimize size differences between plants of the same age by hand planting the seeds and by selecting only plants which met certain criteria at week 3, large differences still existed in plant size each week, and thus larger samples would have been necessary to separate leaf loss from sample variability. It appears in Table 7 that some stress between weeks 7 and 8 caused the plants to lose about 20 leaves and then more leaves were not lost until week 13.

Table 3. Average leaf growth for Florunner peanut plants during the 1978 growing season, as indicated by weekly plant samples.

Week From Planting	LAI*	Growth of Leaves During the Preceeding Week: No. New Leaves	Wt. New Leaves, g	Specific Leaf Wt., mg/cm^2	Weight per Leaf, mg	Total Number of Leaves	Total Leaf Weight, g	Weight per Leaf, mg
3	0.04	10.8	0.2	4.66	20.4	10.8	0.2	20.4
4	0.08	7.4	0.2	4.92	28.4	16.8	0.4	25.6
5	0.16	11.8	0.6	5.05	50.0	28.0	0.9	31.1
6	0.73	24.0	2.0	3.66	81.2	60.8	3.3	54.6
7	1.49	36.5	3.6	4.00	99.3	80.7	6.5	80.3
8	2.05	41.8	3.4	3.68	80.4	109.7	8.7	79.3
9	3.62	50.8	5.0	3.73	98.1	164.1	15.0	91.7
10	3.49	30.7	2.6	3.78	84.1	162.7	13.8	85.1
11	4.97	35.5	2.6	3.27	72.1	223.1	17.6	79.0
12	6.55	50.0	3.5	3.09	69.2	277.8	25.0	89.9
13	5.68	20.7	1.5	3.39	71.1	280.3	21.7	77.4
14	6.23	20.7	1.6	4.02	76.4	261.5	24.8	94.7
15	6.43	3.0	0.2	3.17	50.0	276.5	24.7	89.3
16	6.09	3.3	0.2	3.51	60.0	229.7	22.8	99.3
17**	6.75	0.3	---	---	---	306.0	26.7	87.2
18	6.24	0.0	---	---	---	286.0	25.4	88.7
20	5.15	0.0	---	---	---	226.7	24.3	107.2

*Leaf area index.

**Only 3 plants harvested this week.

Table 4. Average stem growth for Florunner peanut plants during the 1978 growing season, as indicated by weekly plant samples.

Week	Mainstem Length, cm	Total Stem Length, cm	Stem Weight, g	Ratio of Stem Weight to Length, mg/cm
3	5.0	13.5	0.1	9.4
4	5.9	21.5	0.2	8.0
5	7.1	35.1	0.4	9.9
6	9.9	101.2	1.5	13.7
7	12.0	199.5	2.9	14.4
8	18.1	403.8	7.0	16.1
9	23.9	609.2	13.2	18.7
10	29.1	787.4	14.9	18.4
11	35.7	1051.3	22.7	21.1
12	38.9	1267.4	27.4	19.6
13	44.6	1403.4	31.0	23.1
14	43.1	1245.0	30.1	24.9
15	49.2	1483.8	33.6	22.2
16	46.4	1218.6	28.6	23.2
17*	38.8	1408.0	28.7	20.4
18	52.3	1471.7	35.0	22.5
20	40.1	1081.4	26.7	24.8

*Only 3 plants harvested this week.

Table 5. Average numbers and weights of pods present on the Florunner peanut plants harvested each week during the 1978 growing season.

Week	No. P1	No. P2	No. P3	No. P4	P4 Wt., g	No. P5	P5 Wt., g	Kernel Wt., g
7	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	3.3	6.3	1.6	0.0	0.0	0.0	0.0	0.0
9	12.8	13.9	11.1	2.3	0.6	0.8	0.3	0.4
10	18.6	13.2	16.4	8.8	1.9	1.0	0.4	0.4
11	20.3	27.9	34.4	10.4	1.9	18.9	9.3	5.6
12	17.8	44.0	46.7	17.2	2.3	23.0	14.1	9.7
13	16.0	24.3	47.6	20.1	4.6	31.2	24.9	18.3
14	15.9	23.5	30.7	21.9	6.6	30.3	27.4	20.9
15	7.6	20.4	34.4	17.5	5.4	43.0	40.3	31.3
16	6.4	19.3	17.5	14.5	5.9	42.3	48.0	37.3
17*	16.3	22.3	43.7	30.3	11.0	58.3	61.5	49.1
18	9.6	17.5	26.3	22.4	6.5	57.1	63.7	51.4
20	7.7	14.3	14.3	17.6	6.0	55.4	63.6	49.8

*Only 3 plants harvested this week.

Table 6. Number of new leaves per branch during the 1978 growing season, as indicated by weekly plant samples.

Week	Estimated Number of Active Veg. Growing Points/Plant	Estimated Number of New Leaves/ Active Veg. Growing Point
3	---	---
4	4.6	1.6
5	7.8	1.5
6	16.4	1.5
7	26.8	1.4
8	30.1	1.4
9	34.6	1.5
10	28.0	1.6
11	31.3	1.1
12	39.1	1.3
13	17.8	1.2
14	20.7	1.0

Table 7. Estimation of leaf loss by Florunner peanut plants during the 1978 season, as indicated by weekly plant samples.

Week from Planting	No. of New Leaves Grown During Week	Sum of Leaves Added Each Week	Actual Mean No. of Leaves Present per Plant ± 2 SE	Estimated No. of Leaves Lost to date*
3	---	10.8	10.8 ± 2.2	---
4	7.4	18.2	16.8 ± 2.7	1.4
5	11.8	30.0	28.0 ± 6.2	2.0
6	24.0	54.0	60.8 ± 12.5	6.8
7	36.5	90.5	80.7 ± 17.2	9.8
8	41.8	132.3	109.7 ± 28.0	22.6
9	50.8	183.0	164.1 ± 36.5	18.9
10	30.7	213.7	162.7 ± 40.2	51.0
11	35.5	249.2	223.1 ± 66.2	26.1
12	50.0	299.2	277.8 ± 48.4	21.5
13	20.7	319.9	280.3 ± 64.6	39.6
14	20.7	340.6	261.5 ± 63.8	79.1
15	3.0	343.6	276.5 ± 49.0	67.1
16	0.0	343.6	229.7 ± 33.8	113.9
17	0.0	343.6	306.0 ± 45.6	37.6
18	0.0	343.6	286.0 ± 72.4	57.6
20	0.0	343.6	226.7 ± 38.1	116.9

*Column 3 - Column 4

Leaves continued to add weight for a time after they were considered fully expanded in this study. The specific leaf weight of the new leaves each week (Experiment 2) is compared in Table 8 with that of leaves marked during the same week but not harvested until week 16 (Experiment 1).

Pegs were first present on plants harvested at week 7 (Table 5). Pods first started to swell at week 8 and there were fully expanded pods (P4's and P5's) present by week 9. The number and weight of pods in the largest size category (P5's) continued to increase until week 17. The number of aerial pegs (P1's) decreased after week 14.

The branching pattern of Florunner turned out to be more variable than the literature indicated for Virginia peanuts (Gregory et al. 1951, Wynne 1975). According to Gregory et al. (1951), the branching pattern should be vegetative in the first node, mostly vegetative in the second node, then have alternating pairs of reproductive and vegetative nodes. In a study of the first 2 nodes on the 2 cotyledonary laterals and the first 4 branches off the mainstem on 20 plants mapped when leaf and stem growth had essentially stopped, only 72.5% of these branches were vegetative in the first node, and 29.2% in the second node. For the most part, however, the cotyledonary laterals and first 4 branches off the mainstem had more vegetative nodes than expected. There were frequently 3 or 4 vegetative nodes in a row, and sometimes as many as 6. A common pattern was 1 vegetative node, 1 reproductive node, then 3 or 4 vegetative nodes, then alternating pairs of reproductive and vegetative. Later branches for the most part exhibited the expected branching pattern. This variation had the effect of making most early

Table 8. Comparison of specific leaf weights for leaves initiated at the same time but harvested within a week or at week 16.

Interval of Leaf Initiation, Weeks	Specific Leaf Weight, mg/cm^2	
	Leaves Harvested at End of Week	Leaves Marked at End of Week but Harvested at Week 16
0-3	4.66	5.48
3-4	4.92	5.96
4-5	5.05	5.42
5-6	3.66	4.11
6-7	4.00	3.82
7-8	3.68	3.74
8-9	3.73	3.98
9-10	3.78	4.04
10-11	3.27	4.10
11-12	3.09	4.23
12-13	3.39	4.27
13-14	4.02	4.24
14-15	3.17	4.12

nodes vegetative, and this perhaps contributes to the high-yielding capability of Florunner.

Although there was a large amount of variation between plants of the same age in stem length and weight, the ratio of stem weight to length was closely correlated to plant age; in fact, there was a much higher correlation between this ratio and plant age than between it and plant size, when total length of all stems was used as the measure of plant size (Table 9). Internode length and weight also depended more on plant age than on plant size (Table 9). Table 10 is a summary of week versus internode length and internode weight. Both length and weight per internode remained constant for the first 5 weeks after planting, then began to increase. Weight increased steadily until week 16, but average length was somewhat more variable from week to week.

Figure 1 is a graph of the measured canopy light interception versus LAI. The fitted equation has an R^2 value of 0.98.

The results of these experiments as they relate to the development of the plant growth model will be discussed in greater detail in Chapter IV.

Table 9. Results of linear correlations of stem size to plant age and plant size for Florunner peanuts.

Dependent Variable	Independent Variable(s)	R^2
Ratio of stem weight to length	Week of the season	0.78
Ratio of stem weight to length	Total stem length	0.40
Ratio of stem weight to length	Week of the season, total stem length	0.78
Internode weight*	Week of the season	0.80
Internode length**	Week of the season	0.67
Internode weight*	Number of leaves (internodes)	0.46

*Internode weight was estimated by dividing total stem weight by the number of leaves on the plant.

**Internode length was estimated by dividing total stem length by the number of leaves on the plant.

Table 10. Average size of stem internodes during the 1978 season, as indicated by weekly plant samples.

Week	Internode Length, cm*	Internode Weight, mg**
3	1.25	12.3
4	1.27	10.0
5	1.21	12.7
6	1.58	22.1
7	2.31	33.4
8	3.49	57.5
9	3.94	77.0
10	4.43	85.1
11	4.62	97.4
12	5.15	101.1
13	4.96	112.9
14	4.64	114.9
15	5.36	119.3
16	5.46	125.8
17	4.58	93.3
18	5.12	114.8
20	4.70	116.7

*Average internode length for each plant was estimated by dividing the total stem length by the number of leaves (internodes) on the plant.

**Average internode weight for each plant was estimated by dividing the total stem weight by the number of leaves (internodes) on the plant.

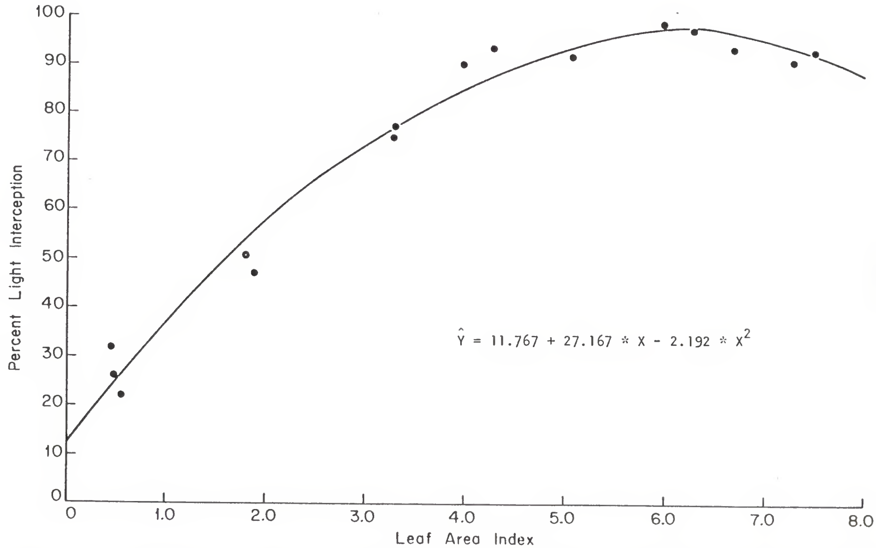


Figure 1. Relationship between leaf area index and percent light interception for Florunner peanuts planted on 24 May 1978.

CHAPTER III
THE EFFECTS OF DEFOLIATION ON PEANUT PLANT GROWTH

Introduction

There have been several studies on the effect of various degrees of defoliation upon final yield in peanuts. There is little in the literature about the physiological response of peanut plants to leaf removal.

Greene and Gorbet (1973) defoliated Florunner peanuts with a mowing machine, approximating 10-15, 20, 33, and 50% defoliation by changing wheel settings. They found that 33% defoliation at several growth stages decreased yields. Since their method of defoliation also removed petioles, stems, and pegs and cut across major trunks of the vascular system of the plant, their results are not applicable in determining the effect of foliage-feeding insects upon the plant.

Enyi (1975), working in Africa, performed defoliation experiments on the Dodoma edible variety of peanuts. In this experiment, flowering began 4 weeks after sowing, pegging at 8 weeks, and podding at 11. He removed either 50% (2 of the 4 leaflets on each leaf) or 100% of the foliage at weekly intervals (plants were defoliated only once). Plants were harvested at the end of the season and dry weights for stems, pods, and seeds determined. Complete defoliation significantly reduced kernel weight and pod number, the greatest reduction occurring when leaves were removed 12 weeks after sowing. Complete defoliation also reduced weight of pods, dry weight of stems, and individual kernel size. Half

defoliation at 8 and 12 weeks significantly reduced the weight of 1000 kernels, while half defoliation at any time between 4 and 14 weeks (the extent of the experiment) significantly reduced pod number per plant and dry weight of stems. In fact, in correlating pod number (N) to stem dry weight (S) he found that a variation in S accounted for about 80% of the variation in N between treatments (R=0.896). A similar correlation existed between pod dry weight and stem dry weight (R=0.913). Defoliation always significantly increased shelling percentage. Enyi hypothesized that defoliation reduced pod number by depressing growth of stems and consequently reducing the number of flowering nodes, the number of pegs formed, and hence the number of pods per plant.

Nickle (1977), working in Gainesville, Florida, defoliated the Florunner variety of peanut from 25 to 100% by removing from 1 to 4 leaflets from each leaf. He defoliated plants at 3, 6 (beginning of flowering), 9 (pegging), 12 (beginning of pod filling), and 15 weeks of age. Some plots were defoliated 50% 2 or more times. For example, 50% of the leaves were removed at 3 weeks and 50% of the new foliage was removed 3 weeks later. He obtained dry weights for the leaves removed at each treatment period, and dry weight and quality of nuts per treatment plot at harvest. For all single defoliation levels he found greatest yield reduction at 9 weeks, followed by 12 weeks. A single defoliation at 3 or 6 weeks resulted in a delay of flower production by as much as 2 weeks. Defoliation at 9-12 weeks inhibited floral production or, if severe, caused flower drop and cessation of flower production. It also resulted in a delay or cessation of the pegging

process. Yields from single defoliations of 50% or more at 9, 12, and 15 weeks had a higher percentage of split and damaged nuts than the controls, but the percentage of sound, whole nuts from multiple defoliation treatments was significantly higher than that from the control.

A comparison of leaf biomass removed in single defoliations with that removed in multiple defoliations indicates that defoliated plants probably put on greater new leaf mass between treatments. For example, 35.6 g/plant total leaf weight was removed from plants defoliated at 9 and 12 weeks, whereas only 30.1 g was removed from plants defoliated at 12 weeks.

Williams et al. (1976) studied the influence of defoliation and pod removal on growth and dry matter distribution of the Makulu Red variety of peanuts in Rhodesia. Normal growth of this variety in Rhodesia, as reported by Williams et al. (1975), proceeds as follows: flowering begins 55 days after planting, continuing until 100 days. Stems increase in weight until 18 weeks after sowing, as does the plant as a whole. Leaf area reaches a maximum at 16 weeks, kernels start to form at 12 weeks, and pegs reach a maximum number at 20 weeks, as do the pods. Kernel number is set at 22 weeks. In their defoliation and depodding experiments, Williams et al. (1976) defoliated 0, 50, or 75% and depodded either 0 or 50% at 3 stages of growth (17, 19, and 21 weeks). They defoliated by removing leaflets from each leaf and depodded by severing at ground level all pegs on one half of the plant. The plants were harvested and measured 2 weeks after the treatment. Defoliation at all periods greatly increased leaf growth rate over the control. At 17 and 19 weeks, defoliation of 75% increased leaf growth rate more than 50% defoliation did. The reverse occurred at 21 weeks.

Stem growth rate was correspondingly slowed by defoliation. In plants that were both depodded and defoliated, stem growth rate was not as severely decreased as in plants with only defoliation. The results also indicated that few if any pods were initiated when the plants were depodded at 21 weeks--in fact the plants appeared to abort pods at this stage if they were defoliated but not depodded. Williams et al. (1976) hypothesized that the increased leaf growth with defoliation and corresponding decrease in stem growth could be accounted for by increased mass per unit area of leaf, due possibly to greater accumulation of assimilated material in leaves no more completely illuminated.

Differences in branching patterns between varieties of peanuts may affect the response to leaf removal. Smith and Jackson (1974) found that defoliation of Florunner decreased final yeild less than did an equal percentage of defoliation of Starr peanuts (a Spanish variety). This difference might be explained by the determinate branching system of Spanish peanuts (Gregory et al. 1951) as opposed to an indeterminate branching pattern in Florunner and the consequent ability of Florunner to put on more new leaves when defoliated. Fehr et al. (1977) found that defoliated determinate cultivars of soybeans had significantly greater yield reduction than did indeterminate cultivars similarly defoliated. They also found that the indeterminate cultivars put on more new leaves following defoliation than did the determinate ones. In addition, the number of new leaves produced after defoliation significantly exceeded the number for the untreated check at some growth stages. Rudd et al. (1980), in modelling soybean growth, found that their model overestimated the damage done to final yield by 1 mechanical

defoliation just prior to pod appearance unless they allowed the plant to "compensate" for leaf loss by using photosynthate destined for temporary storage in the stems to produce extra leaves instead.

The experiments discussed in this chapter were designed to determine the effects of mechanical defoliation on certain aspects of plant growth. Severe uniform defoliation (50% or more) appears to have the effect of increasing growth of leaves (Nickle 1977, Williams et al. 1976) and decreasing stem growth (Enyi 1975, Williams et al. 1976), at least until fairly late in the season. This could happen if leaves left on the plant gain in weight (as suggested by Williams and his co-workers) and stems stop or slow down growth (as suggested by Enyi). Alternatively, the plants might grow leaves at an increased rate at current growing points and/or initiate new growing points at previously inactive vegetative nodes. New growing points might be initiated only in places where light penetrates due to the defoliation. This increased growth of leaves when photosynthetic supply has been decreased could be accomplished by depletion of storage reserves (probably in the stems) or by a change in the partitioning of available photosynthate to the various plant organs.

It appeared likely that defoliation at different times in the season would have different effects on plant growth. Early in the season with the plants growing at a maximum rate, defoliation was expected to have the effect of slowing down vegetative growth of the plant and thus delaying the time of full ground cover, and podsetting during pegging and podsetting. It was hypothesized that defoliation would decrease the number of fruit set, due to a decrease in available photosynthate and a shift in photosynthate partitioning to new leaves at a

time when vegetative growth would normally be decreasing. After the pod load is set, defoliation was expected to result in the plant filling fewer pods.

There are indications that defoliating caterpillars may attack younger leaves or terminal buds (vegetative growing points) preferentially (Huffman 1974, Arthur et al. 1959, Morgan 1979). I anticipated that the type of defoliation would make at least some difference in the plant response. Most prior defoliation experiments on peanuts have dealt with uniform defoliation (removing a certain number of leaflets from each leaf). It appeared likely that this would change light interception and plant growth in a different manner than an equal amount of non-uniform defoliation (removing an outer layer of leaves, for example).

Four defoliation experiments were performed to investigate these questions about plant response to defoliation. The purpose of the early season defoliations was to determine the effect of several levels of defoliation and the effect of removal of vegetative meristems alone or in combination with partial or complete defoliation. The second and third defoliations investigated the effect on subsequent plant growth of severe defoliation (50%) by 2 different methods (removing 2 leaflets from each leaf, or removing 100% of the leaves from the outer 50% of the canopy) at the pegging and podsetting stages of growth. The final experiment dealt with the effect of 50% uniform and total defoliation late in the season. The 50% defoliation treatment was for comparison with the earlier experiments; the 100% defoliation was intended to reveal the presence or absence of storage reserves in the stems, as

vegetative growth should have ceased prior to defoliation time. All the experiments were designed to determine growth of new leaves, growth of pods, and growth of stems, as indicated by changes in length, weight, and length to weight ratio, following defoliation.

Methods and Materials

First Defoliation

The first defoliation plot was planted on 22 May with a row and intrarow spacing identical to that described in Chapter II. Other aspects of crop management were identical also. The plants were defoliated on 23 June, 4½ weeks after planting.

The experiment consisted of 7 treatments applied to 5 blocks. Plants were blocked by row. Seven treatment plots were selected in each row with at least 2 plants between treatments. Each treatment plot consisted of 5 plants, but only the 3 interior plants were included in the sample.

The 7 treatments were:

1. Check
2. 25% uniform defoliation
3. 50% uniform defoliation
4. 100% uniform defoliation
5. 50% uniform defoliation + 100% of the vegetative growing points
6. 100% defoliation + 100% of the vegetative growing points
7. 0% defoliation + 100% of the vegetative growing points.

Uniform defoliation refers to removing the same number of leaflets from each 4-leaflet leaf on the plant. Only leaves which had another leaf starting to open above them on the branch were defoliated or marked. Growing points were removed by snapping off newly forming leaves as far down within the stem as possible.

Plants in treatments 1 and 7 were marked with surgical wound clips and acrylic paint as discussed in Chapter II. A surgical wound clip was placed around the petiole of each fully expanded leaf, and all stems were marked with a spot of paint. The stems of treatments 2 - 6 plants were also marked with paint and the defoliation process itself adequately marked the leaves. Removed leaflets from each treatment were measured and then dried and weighed.

The plants were harvested 7 weeks after planting--2½ weeks following treatment. One plant from each treatment plot was selected for mapping. This plant was the "average" plant in that it was intermediate in size between the other 2 sample plants contained in the plot. The positions of new and old leaves and branches were noted and each stem was given a code number and measured. Each harvested plant was broken down into the following parts: old leaves, new leaves, petioles, stems, vegetative growing points, pegs and reproductive branches, and pods. Leaves were counted and a subsample was measured for leaf area. The numbers of new and old stems and number of pegs were obtained. All stems were measured. The various plant parts were then dried and weighed.

Canopy light interception was measured for each treatment plot in 2 rows just before the plants were harvested, in the manner discussed in Chapter II.

Second Defoliation

Plants for this experiment were in the same field as those in Chapter II, and all crop management practices were identical. The plants were defoliated 9 weeks after planting, and half were harvested 2 weeks after treatment; the other half 6 weeks post treatment. The experiment consisted of 6 treatments applied to 4 blocks. Plants were again blocked by row, there being a buffer row between treatment rows and at least 2 plants between treatment plots in a row. Again there were 5 plants per treatment plot, but only the interior 3 were included in the sample. Plants were dug up by shovel to save as many pods and roots as possible.

The 6 treatments were:

1. Check--harvested at 11 weeks
2. 50% uniform defoliation--harvested at 11 weeks
3. Removal of all leaves from the outer 50% of the canopy--harvested at 11 weeks
4. Check--harvested at 15 weeks
5. 50% uniform defoliation--harvested at 15 weeks
6. Removal of all the leaves from the outer 50% of the canopy--harvested at 15 weeks.

For treatments 3 and 6 the outer 50% of the canopy was determined on a volume basis. Several measurements were made to determine the average height and width of the canopy and the cross-sectional area was calculated using the formula for an ellipse. The proper height and width were then calculated to obtain a canopy with only ½ the original cross-sectional area. Wires were bent across the canopy delineating this

area and all leaves falling outside of the wires were removed; those inside were left alone.

Leaves and stems were marked in a manner similar to that of previous experiments except only the last 2 leaves on each branch were marked. Pegs that had entered the ground also were marked with wound clips. In this experiment any newly emerging leaf also was removed if the petiole was extended sufficiently for a wound clip to be placed around it.

When the plants were harvested, plant parts were separated, weighed, counted, and measured as in the other experiments and 1 plant from each treatment plot was mapped. This time pods were divided into marked versus unmarked and then into size categories P3-P5. After drying and weighing, nuts in the P5 category (fully expanded shell which did not shrink upon drying) were shelled and weighed.

Canopy light interception measurements were made in the treatment plots the day after defoliation and just before the 2-week harvest.

Third Defoliation

The third defoliation was performed when the plants were 12 weeks old. This experiment was identical to the second defoliation except that pegs were not marked and plants were harvested 2 and 4 weeks after treatment.

Fourth Defoliation

The last series of defoliations took place when the plants were 16 weeks of age. As it was late in the season, the treatments were 50% uniform and 100% defoliation. All plants were harvested 2 weeks later.

As there was little vegetative growth at this late stage, no plant maps were made.

Table 11 is a summary of the times and types of defoliations made during the course of the season.

Results

First Defoliation

The results are summarized in Table 12. All plant parts appeared to be affected equally by defoliation, i.e., if stem weight was reduced, so were stem length and leaf number and weight (Table 13). The fact that the average values for the 50% defoliation treatment were generally higher than those for the 25% defoliation treatment (Table 12) is perhaps due to the higher initial LAI for the 50% defoliation plots. Mean LAI for the 25% defoliation plots was 0.10 just prior to defoliation, whereas that for the 50% defoliation plots was 0.16. The unevenness of planting depth caused some problems in that plants emerged at different times and this had an effect upon plant size throughout the season. Blocking by row partially overcame this problem as is indicated by significant differences ($\alpha = .05$) between rows in average cotyledonary lateral length, total stem length, root weight, and the number of old leaves. There was variation in plant emergence and size within rows too and this resulted in the plants in some treatment plots being larger on average than those in other treatment plots prior to defoliation.

Plant response to growing tip removal was quite uniform. Removing the apical meristem destroyed apical dominance. If either of the first

Table 11. Summary of the defoliation experiments performed during the 1978 growing season on Florunner peanut plants.

Week from Planting	Treatment Number	Treatment Type	Week Harvested
$4\frac{1}{2}$	1	Check	7
	2	25% uniform	7
	3	50% uniform	7
	4	100%	7
	5	50% uniform + veg. growing pts.	7
	6	100% uniform + veg. growing pts.	7
	7	0% + vegetative growing points	7
9	1	Check	11
	2	50% uniform	11
	3	Outer 50% of the canopy	11
	4	Check	15
	5	50% uniform	15
	6	Outer 50% of the canopy	15
12	1	Check	14
	2	50% uniform	14
	3	Outer 50% of the canopy	14
	4	Check	16
	5	50% uniform	16
	6	Outer 50% of the canopy	16
16	1	Check	18
	2	50% uniform	18
	3	100%	18

Table 12. The effect of various levels of defoliation at $4\frac{1}{2}$ weeks upon plant size at 7 weeks.

Treatment	Mainstem Length, cm*	Stem Length, cm*	Avg. Cot. Lat. Length, cm*	Stem Weight, g*	Ratio of Stem Wt. to Length, mg/cm*
Check	17.5 (0.7)	298.5 (32.2)	23.1 (1.1)	4.0 (0.6)	12.9 (0.4)
25% uniform	14.8 (0.7)	216.8 (28.3)	18.7 (1.5)	2.8 (0.5)	12.5 (0.4)
50% uniform	16.7 (0.8)	250.0 (31.6)	21.5 (1.2)	3.5 (0.5)	13.4 (0.5)
100%	13.9 (0.9)	192.2 (26.8)	16.5 (1.6)	2.3 (0.4)	11.6 (0.4)
0% + vegetative growing points	12.4 (0.9)	206.3 (24.6)	14.8 (1.1)	2.5 (0.4)	11.3 (0.7)
50% + vegetative growing points	12.2 (0.5)	143.8 (16.2)	13.6 (1.1)	1.6 (0.2)	10.8 (0.5)
100% + vegetative growing points	10.8 (0.5)	94.6 (10.8)	10.8 (0.7)	0.9 (0.1)	9.6 (0.5)

*Number in parentheses is standard error of the mean.

Table 12. Continued

Treatment	Number of Veg. Growing Points*	Number of New Leaves*	Weight of New Leaves, g*	Root Weight, g*	Total Plant Weight, g*
Check	31.8 (3.2)	72.2 (6.4)	5.2 (0.7)	0.6 (0.1)	14.4 (1.9)
25% uniform	28.5 (2.0)	57.4 (4.7)	3.9 (0.5)	0.6 (0.1)	10.8 (1.5)
50% uniform	30.9 (3.0)	61.4 (6.0)	5.0 (0.6)	0.6 (0.1)	13.0 (1.6)
100%	28.7 (3.4)	54.1 (5.6)	3.4 (0.5)	0.5 (0.1)	8.3 (1.2)
0% + vegetative growing points	25.7 (1.4)	52.6 (5.2)	3.0 (0.4)	0.5 (0.1)	9.2 (1.3)
50% + vegetative growing points	24.5 (2.6)	45.5 (4.2)	2.1 (0.3)	0.4 (0.1)	6.4 (0.9)
100% + vegetative growing points	18.7 (2.1)	32.6 (3.0)	1.0 (0.1)	0.3 (0.0)	3.4 (0.4)

*Number in parentheses is standard error of the mean.

Table 13. Estimated leaf and stem gains in the $2\frac{1}{2}$ weeks following defoliation at $4\frac{1}{2}$ weeks.

Treatment	Estimated Original Stem Wt., g*	Estimated Gain in Stem Wt., g	Gain in Leaf Wt., g	$\frac{\Delta Leaf}{\Delta Leaf+\Delta Stem}$
Check	3.0	3.7	5.2	0.58
25% uniform	2.8	2.6	3.9	0.60
50% uniform	3.6	3.1	5.0	0.62
100%	3.6	1.9	3.4	0.64
0% + tips	3.5	2.1	3.0	0.58
50% + tips	3.2	1.3	2.1	0.62
100% + tips	4.8	0.4	1.0	0.70

*Original stem weight was estimated by dividing the original leaf weight by 0.70 to find stem weight + leaf weight. Subtracting leaf weight from this gave original stem weight. (The ratio of leaf weight to leaf + stem weight averaged 0.70 for non-defoliated plants until week 8.)

2 nodes below the destroyed tip was vegetative, a new branch would grow out of the end of the former branch, with only a scarred stub over to one side to mark the end of the original branch and the beginning of the new. The branching pattern of this new stem was that expected for a vegetative branch, there being no leaf at the first node. If the 2 nodes directly below the destroyed tip were both reproductive then a flower would emerge at both nodes, but there would be no vegetative growth.

Table 14 is a summary of the light interception results for this experiment. The weather was unsuitable for taking measurements for several days prior to harvest and it was therefore not possible to make as many readings as necessary to obtain an accurate picture of LAI versus percent light interception.

Second Defoliation

Tables 15 and 16 are summaries of the results for plants harvested at 11 and 15 weeks, respectively. In the removal of all the leaves from the outer 50% of the canopy in treatments 3 and 6, more than 50% of the leaf matter by weight was removed. Two weeks after treatment, plants defoliated 50% uniformly had as many new leaves as non-defoliated plants, and the ratio of stem weight to length was significantly reduced. Plants from which the exterior 50% of the canopy was removed had significantly more leaves than non-defoliated plants. They also had significantly more new vegetative growing points and a significantly reduced stem weight to length ratio. Weight of new leaves was also significantly higher. A study of the plant maps indicated that the new

Table 14. Summary of light interception by plants 7 weeks of age which had been defoliated at $4\frac{1}{2}$ weeks.

Treatment Type	Row	LAI	Percent Light Intercepted
Check	B	1.89	46.9
	E	1.80	50.8
25% uniform	B	1.53	48.4
	E	0.62	29.6
50% uniform	B	1.06	33.3
	E	1.78	36.9
100%	B	0.77	32.0
	E	0.68	36.6
50% uniform + tips	B	0.66	44.7
	E	0.42	22.7
100% + growing tips	B	0.27	20.2
	E	0.35	20.6
0% + growing tips	B	0.82	26.9
	E	1.39	24.7

Table 15. The effect of 50% defoliation at week 9 upon plant size at week 11.

Plant Variable	Treatment		
	Check	50% Uniform	Outer 50% of Canopy
Number of new leaves	52.9b	56.7b	86.8a
Weight of new leaves, g	4.4b	5.3ab	7.0a
Ratio of stem weight to length, mg/cm	21.3a	18.1b	18.7b
Number of vegetative growing points	49.6b	58.1ab	72.2a
Number of new vegetative growing points	14.4b	14.1b	25.9a
Number of P1*	19.3b	27.1ab	35.1a
Number of P5	19.8a	13.9ab	7.7b
P5 weight, g	9.9a	7.0a	4.0b
Kernel weight, g*	6.0a	4.2ab	2.6b

Note: Means in a row followed by the same letter are not significantly different according to a t-Test (α = 0.05 except for plant variables marked with an *, in which case α = 0.10).

Table 16. The effect of 50% defoliation at week 9 upon plant size at week 15.

Plant Variable	Treatment		
	Check	50% Uniform	Outer 50% of Canopy
Number of new leaves*	105.2b	107.3b	138.8a
Ratio of stem weight to length, mg/cm	22.8a	20.9b	18.2c
Mainstem length, cm	51.9a	44.6b	44.3b
Average cotyledonary lateral length, cm	71.3a	61.6b	60.7b
Number of new vegetative growing points	12.4b	16.8ab	21.8a
Number of P1	4.6b	8.2ab	12.2a
Number of P3*	38.6a	27.2ab	20.0b
Weight of P3, g*	1.0a	0.6ab	0.5b
Number of P5*	47.1a	36.1ab	31.6b
Weight of P5, g	44.8a	34.3ab	28.3b
Kernel weight, g	35.0a	27.2ab	22.6b

Note: Means in a row followed by the same letter are not significantly different according to a t-Test (α = 0.05 except for plant variables marked with an *, in which case α = 0.10).

vegetative growing points arose toward the exterior of the canopy, frequently in the axils of defoliated leaves.

The results for plants harvested at week 15 were similar to those for plants harvested at 11 weeks. By this time, mainstem length and average cotyledonary lateral length were significantly lower for defoliated plants.

There was a significant effect (α=.05) of block (row) on mainstem length, number of P2 (pegs in ground), number of P5 (fully expanded pods which did not shrink when dried), P5 weight, kernel weight, and weight of all pods (P3-P5) at 11 weeks. This was probably due again to the difference in emergence times of different rows. By week 15, row had a significant effect only on root weight and the ratio of stem weight to length.

Light interception by plants harvested at week 11 is summarized in Table 17. Average light interception immediately following defoliation by plants defoliated uniformly was 83% of that of the check plants; average light interception by plants defoliated non-uniformly was 69% of that of the check plants at the same time. There was no difference in light interception 2 weeks after treatment between defoliated and non-defoliated plants.

Third Defoliation

The response of plants defoliated at week 12 was similar to that of plants defoliated at week 9 in that the plants from which leaves were removed had an equal or greater growth of leaves, as indicated by number and weight of new leaves per plant, and a reduction in stem weight to length ratio as compared to the check plants (Tables 18 and 19). More than half of the leaf material by weight was removed in

Table 17. Summary of light interception by plants defoliated at 9 weeks of age.

Treatment	Row	Estimated LAI Immediately After Defoliation	% Light Interception Immediately After Defoliation	LAI at 11 weeks	% Light Interception at 11 weeks
Check	F	2.8	82.2	4.0	90.1
	G	4.7	59.1	6.3	97.2
	H	---	---	3.3	77.1
50% uniform	F	2.3	56.6	4.1	91.0
	G	1.5	56.8	2.9	96.0
	H	---	---	---	71.5
Outer 50% of canopy	F	1.0	56.0	2.7	94.4
	G	1.7	42.2	3.9	96.1
	H	---	---	2.9	79.9

Table 18. The effect of 50% defoliation at week 12 upon plant size at 14 weeks.

Plant Variable	Treatment		
	Check	50% Uniform	Outer 50% of Canopy
Number of new leaves	10.1b	15.1b	32.0a
Weight of new leaves, g	0.9b	1.3b	2.1a
Ratio of stem weight to length, mg/cm	25.3a	22.5b	20.5c
Number of vegetative growing points	45.5b	41.7b	60.6a
Number of new vegetative growing points	6.2b	4.2b	10.8a
Number of P3	26.9b	29.9b	49.3a

Note: Means in a row followed by the same letter are not significantly different according to a t-Test ($\alpha = 0.05$).

Table 19. The effect of 50% defoliation at week 12 upon plant size at week 16.

Plant Variable	Treatment		
	Check	50% Uniform	Outer 50% of Canopy
Number of new leaves	22.3b	26.5b	55.0a
Weight of new leaves, g	1.6b	1.9b	3.7a
Ratio of stem weight to length, mg/cm	23.4a	21.8ab	20.6b
Average cotyledonary lateral length, cm	67.9a	65.9ab	60.6b
Number of new vegetative growing points	5.2b	3.8b	8.9a
Number of P1	5.7b	13.0a	13.9a
Number of P5	44.4a	39.9ab	28.2b
Weight of P5, g	51.8a	46.9ab	33.8b
Kernel weight, g	40.5a	36.7ab	27.2b
Total plant weight, g*	125.6a	110.5ab	90.5b

Note: Means in a row followed by the same letter are not significantly different according to a t-Test (α = 0.05 except for plant variables marked with an *, in which case α = 0.10).

Treatment 6, but in Treatments 2 and 3 essentially identical amounts of leaf material were removed. Of the plants harvested at 14 weeks, plants which were defoliated non-uniformly had an increase in number of growing points and in number of small pods (P3). By 16 weeks, defoliated plants had significantly more aerial pegs, but the number and weight of mature pods (P5) were lower, although the difference between check and 50% uniform defoliation plants was not significant.

For the plants harvested at 14 weeks, block (row) had a significant effect only on weight of P4's (fully expanded pods which shrivel). For those removed at 16 weeks, there was a significant difference between rows for number of new growing points and leaf weight prior to treatment.

Light interception data are summarized in Table 20. Average light interception immediately following defoliation by plants defoliated uniformly was 86% of that by the check plants; average light interception by plants defoliated non-uniformly was 81% of that of the check plants at the same time. Again, there was no appreciable difference in light interception between check and defoliated plots 2 weeks post treatment, although LAI was much less in the defoliated plots than in the check plots.

Fourth Defoliation

There was a significant difference between treatments for only 3 of the variables considered in this late season experiment. As can be seen in Table 21, the only discernible differences were in number and weight of new leaves and ratio of stem weight to length. The order of response was the same as in the previous experiments--the more serious

Table 20. Summary of light interception by plants defoliated at week 12.

Treatment	Row	LAI Immediately After Defoliation	% Light Interception After Defoliation	LAI at 14 Weeks	% Light Interception at 14 Weeks
Check	J	4.8	90.7	5.1	91.6
	K	3.1	85.2	3.3	75.2
	L	7.3	92.9	7.5	92.6
	M	7.1	92.6	7.3	90.6
50% uniform	J	2.3	69.9	2.5	84.9
	K	2.2	81.1	2.5	94.3
	L	3.7	87.7	3.9	85.9
	M	2.5	72.9	3.0	88.8
Outer 50% of canopy	J	2.8	62.2	3.4	91.1
	K	2.5	86.2	2.8	90.9
	L	2.6	68.2	3.3	79.5
	M	2.5	76.3	3.1	85.4

Table 21. The effect of defoliation at 16 weeks upon plant size at 18 weeks.

Treatment	Number of New Leaves	Weight of New Leaves, g	Ratio of Stem Weight to Length, mg/cm
Check	6.1b	0.1b	22.5a
50% uniform	13.9b	0.3ab	21.2ab
100%	33.0a	0.6a	19.2b

Note: Means in a column followed by the same letter are not significantly different according to a t-Test ($\alpha = 0.05$).

the level of defoliation, the more new leaves were grown and the more the stem weight to length ratio was reduced. Plants defoliated 50% intercepted 80% as much light immediately following defoliation as did the check plants (Table 22). Plants from which all leaves had been removed still intercepted 46% as much light as the check plants. Plants did not put on sufficient new leaf matter following defoliation for canopy light interception to recover.

Table 22. Summary of light interception by plants defoliated at 16 weeks.

Treatment	Row	LAI Immediately After Defoliation	% Light Interception Immediately After Defoliation	LAI at 18 Weeks	% Light Interception at 18 Weeks
Check	R	6.7	94.0	6.7	93.4
	S	4.3	90.9	4.3	93.5
	T	8.1	95.5	8.1	--
	U	6.0	96.0	6.0	98.5
50% Uniform	R	3.3	75.4	3.4	89.1
	S	3.0	73.1	3.0	90.2
	T	3.7	84.4	3.8	--
	U	2.6	68.6	2.6	80.0
100%	R	0.0	40.8	0.1	33.1
	S	0.0	51.8	0.3	61.1
	T	0.0	41.5	--	--
	U	0.0	40.1	0.03	49.2

CHAPTER IV
THE SIMULATION MODEL

Introduction

The experiments discussed in Chapters II and III yielded much of the information necessary for modification of Duncan's (1974) PENUTZ model. From the experiments dealing with the normal growth of non-defoliated plants, I was able to establish the branching pattern of an average plant, the rate of initiation of leaves and vegetative and reproductive branches at different times in the season, the average size of individual leaves and internodes at different times in the season, and the relationship between LAI and percent light interception by the canopy.

My overall conclusions from the defoliation experiments were that the Florunner cultivar of peanuts does accumulate stem storage reserves, and that defoliated plants draw upon these reserves and continue to grow leaves of the same size as non-defoliated plants at active vegetative nodes. If the level of defoliation is severe enough to expose to the light inactive vegetative nodes that would normally be shaded, some of these nodes are activated. Severe defoliation during the pegging and podsetting stages of growth results in fewer pods of the largest size category. When the defoliation occurs early in the pod filling period, expansion of small pods (P3's) is curtailed. When defoliation occurs late in the season after vegetative growth has almost ceased,

stem reserves are apparently used for seed growth, as very little new leaf material is added.

The morphogenetic approach to crop modeling is based on the assumption that individual plant organs have maximum potential growth rates or sink strengths which may vary with temperature and may not be achieved on any given day if substrate is limiting. In order to construct a morphogenetic model, it is necessary to estimate the maximum potential growth rates for the various plant organs, such as leaves and pods, and to provide rules for the division or partitioning of the available carbohydrate and nitrogen on any day when there are insufficient amounts to fill all demands.

From the results of the experiments dealing with normal plant growth, an estimate of maximum average leaf size could be obtained. Dividing this by the number of days required for growth of the leaf provided an estimate of the maximum potential growth rate for leaves. PENUTZ contained estimates of the maximum growth rates for seeds and shells. An estimate of maximum growth rate for individual stem internodes was somewhat more difficult to obtain. In order to do so, I assumed that the ratio of leaf weight to stem weight of 2.15, which held for the first 7 weeks of plant growth, was equal to the ratio of maximum growth rate for an individual leaf to that for an individual stem internode. Estimates were therefore available for maximum growth rates of individual leaves, shells, seeds, and stem internodes.

Many small roots are lost when plants are harvested, and root nodules require carbohydrate for nitrogen fixation. This makes calculation of root demands difficult. A decision was made to exclude roots from the daily balancing of potential growth versus available substrate

in the model being developed. The handling of root growth and nitrogen fixation in the model will be discussed later in this chapter.

Establishing rules for the division of carbohydrate and nitrogen each day was less clearcut than determining potential growth rates for the various plant organs. Although it was clear from the field data (Table 2) that the pod load was set by the end of week 12, it was not clear by what mechanism the size of the pod load was determined. Nor was it obvious by what means the gradual inactivation of growing points could be programmed, especially in view of the increased leaf growth following defoliation. My overall approach to balancing supply and demand was to assume that leaf demands were given higher priority than most other demands when LAI, as an indicator of canopy light interception, was low; but that this priority was moderated by increasing pod demands later in the season. Several different sets of priority rules were tried before one which produced realistic simulations for both normal and defoliated plants was found.

Insofar as possible, parameter values used in PENUTZ were used initially in PMINUS, the morphogenetic model derived from PENUTZ. The results of the experiments dealing with normal plant growth were used for estimation of new parameters involved in computation of leaf and stem growth. When there was no experimental information available for estimation of a particular parameter value, such as the length of time a peg could remain in the ground before becoming incapable of swelling into a pod, a value was chosen which gave a good visual fit between simulated and experimental plant growth. Changes were necessary in some model parameters taken from PENUTZ in order for simulated plant growth to match that observed in the field. New estimates for these parameters

were obtained from the results of the experiments dealing with normal plant growth. After the model simulated normal plant growth satisfactorily, the defoliation experiments were simulated. These simulations produced some unrealistic results, such as too much pod growth and too little stem growth following defoliation, and thus further changes were made in the model so that it satisfactorily simulated not only the growth of the non-defoliated plants, but that of all defoliated plants as well. The changes generally pertained to parameters or processes for which there were no data available for direct calculation of values.

Description of the Model

PMINUS is programmed in GASP IV, a combined continuous/discrete FORTRAN based simulation language (Pritsker 1974). The short main program reads the climate cards for the growing season (which contain daily values for radiation, maximum and minimum temperatures, and rainfall and irrigation) and then calls the executive subroutine GASP, which handles the calling of the other subroutines. A brief description of the user-written subroutines included in PMINUS is given in Table 23. PHZDAZ and RUTNOD are the same as their counterparts in PENUTZ except for minor changes. The subroutines PTOTAL, PLTGRO, DIVIDE, and FRUFIL are adapted from subroutines of the same name in PENUTZ but differ in some major respects. INTLC, EVNTS, SCOND, STATE and OTPUT were added to convert PENUTZ from straight FORTRAN to GASP IV. BEGIN, LEAVES, GRPTS, STEMS, and PNTLAI are new subroutines which calculate the growth of the vegetative portions of the plant. INSECT and ATTAC simulate the effect

Table 23. A brief description of the user-written subroutines included in PMINUS.

Subroutine	Description
INTLC	Initializes some model variables
EVNTS	Computes changes in system status which occur whenever an event occurs
SCOND	Checks state variables at the end of each time step to determine if any of them crossed a specified threshold, thereby triggering a state event
BEGIN	Called at time of plant emergence to initialize plant variables
STATE	Each day calls the subroutines which calculate environmental changes and plant growth
WATERX	Calculates water stress factor--at present a dummy subroutine
PTOTAL	Calculates carbohydrate and nitrogen available to each plant each day
PLTGRO	Calculates sink demand for various plant organs, initiates new leaves, branches, and pegs and calls the subroutines which divide the available carbohydrate and nitrogen
LEAVES	Calculates daily growth of leaves
DIVIDE	Calculates amount of carbohydrate and nitrogen available for pod growth and calls FRUFIL
FRUFIL	Calculates daily growth of pods
GRPTS	Initiates new vegetative growing points
STEMS	Calculates daily growth of stems
PNTLAI	Calculates percent light interception for use in photosynthetic equations
PHZDAZ	Calculates number of physiological days in each calendar day
RUTNOD	Calculates daily growth of roots and nitrogen manufacture
ATTAC	Describes time and type of insect invasion or mechanical defoliation and calls INSECT
INSECT	Calculates effect of defoliation each day on leaf area, leaf weight, and canopy light interception and initiates special growing points if damage is severe enough

Table 23. Continued

OTPUT	Prints results of the simulation
BLK DATA	Provides initial values for many model variables

of an insect invasion and defoliation on the plant. Flow charts of the major subroutines are contained in Appendix 2. A complete listing of PMINUS is given in Appendix 3, a description of model parameters in Appendix 4, and a glossary of input parameters and variable names in Appendix 5.

PMINUS computes growth on a square meter basis. The growth of an average plant is calculated each day and this is multiplied by the number of plants/m^2 to determine growth/m^2. In actuality, program storage and model structure are such that up to 7 plant types may be simulated. Growth/m^2 is then calculated by multiplying the amount of growth of plants of a given type (1-7) by the number of plants of that type/m^2, and then summing over all 7 plant types. This structure was originally devised so that seedling emergence could be spread over several days, giving plants of different sizes. It could also be used to simulate the effect of uneven defoliation over a field.

Subroutine STATE is called by GASP on a daily basis and it in turn calls the other subroutines to calculate plant growth each day. Most plant growth processes are dependent upon physiological time, which is calculated each day by PHZDAZ. The daily minimum and maximum temperatures are used to compute the number of physiological days in a given calendar day. One physiological day equals 75°F. If the average of the maximum and minimum temperature is greater than 75°F then there is more than 1 physiological day in that calendar day. There are an average of 1.2 physiological days per calendar day during the summertime in this part of Florida.

Initiation of New Leaves and Branches

Plants emerge 11 physiological days after planting with a fully expanded leaf on the mainstem, 3 partially developed leaves on the mainstem, and 2 partially developed leaves on each cotyledonary lateral. In the field experiments, plant emergence began on the fifth day following planting, and plants continued to emerge for more than 2 weeks, although the plants used in the experiments were those that emerged during the first 9 days of the emergence period. The earliest leaves expanded more quickly than later leaves. It was easier to simulate this by having the plants emerge later than they did in actuality with some leaves already forming, than by having the earliest leaves grow more rapidly than later ones and draw upon seed reserves.

The program keeps track of the number of branches, both vegetative and reproductive, on each plant, and the date of initiation of the last 2 leaves on each vegetative stem. When the first leaf on a branch is half-grown, a new leaf is initiated on that stem. When a leaf completes development then a new leaf is initiated, and a new branch, either vegetative or reproductive, may be initiated 2 nodes back on the stem. Whether the new branch is vegetative or reproductive depends on the fixed branching pattern of the plant. Suppose, for example, that the stem in question is the first lateral off the mainstem and that it has 1 node with no attached leaf, 4 fully developed leaves at nodes 2-5, a leaf completing development at node 6, and a half-grown leaf at node 7 on day K. There should already be a vegetative branch at node 1, a reproductive branch at node 2, and another vegetative branch at node 3. On day K the leaf at node 6 completes development, and a branch can be initiated at node 4. This branch will be

vegetative according to the plant's branching pattern. A new leaf is also set to start development the next day at node 8.

Each leaf grows for a set number of physiological days. This number depends on the stage of development of the plant. Up until 82 physiological days (about 68 calendar days) after planting, a leaf takes 10.8 physiological days (about 9 calendar days) to develop. This rate of growth yields about 1.4 leaves/branch/week, in keeping with the field results for weeks 4-10 presented in Table 6. Late in the season (after day 82), leaves take 14.4 physiological days to complete development. This yields approximately 1.1 leaves/branch/week, again in accordance with the results in Table 6. The underlying cause for this apparent decrease in growth rate could not be determined, and it may have been due to non-linearity in the leaf growth versus temperature response curve.

In the model a maximum of 333 vegetative growing points/m^2 are allowed. In the field there may be many more than this present, but in my plot this was the maximum number of active ones present at any one time (35/plant, on the average). It was simpler to stop the initiation of growing points when the maximum/m^2 was reached, rather than to program the simultaneous initiation and shutdown of branches.

The length of time between nodes on a reproductive branch is set at 6.0 physiological days in the model. A maximum of 4 nodes is allowed per reproductive branch. In the field there are occasionally more than 4 nodes per branch. The model does not keep track of flowers and pegs separately; rather, once a reproductive node has been activated, a pod may start to swell at that node 27.0 physiological days later.

Calculation of the Day's Net Photosynthate

The photosynthetic equations used in PMINUS are essentially the same as those used in PENUTZ. First, gross photosynthate is calculated by the following equation:

$$PTS = PLTLAI * CLIMAT(NOW,1) * PSLOPE * PTSFAC \quad (1)$$

where PLTLAI is a measure of canopy light interception, CLIMAT(NOW,1) is total radiation in langleys, PSLOPE is the slope of the photosynthetic equation (0.0836g/langley), and PTSFAC is a factor which changes with cultivar, as some cultivars have higher photosynthetic rates than others. Photosynthate is then reduced as follows:

$$PTS = PTS * STRESF * DECFCT \quad (2)$$

where STRESF denotes reduction in photosynthesis due to water stress and DECFCT represents lost photosynthetic efficiency of an aging canopy. Net photosynthate/m^2 is then calculated by the equation

$$PTS = PTS - PTS * RESPFC - BMETFC * STLFRT \quad (3)$$

where RESPFC is a growth respiration factor (0.30), BMETFC is the maintenance respiration coefficient (0.01), and STLFRT is the dry weight of stems, leaves, and petioles. This calculation of net photosynthate differs from Duncan's in that it is calculated on a square meter rather than per plant basis. PLTLAI is also calculated in a different manner. In PENUTZ, PLTLAI is the ground area covered by 1 plant. In PMINUS, PLTLAI is a measure of percent light interception and it is determined from the LAI versus percent light interception equation developed in Chapter II:

$$PLTLAI = (11.767 + 27.167 * SS(1) - 2.192 * SS(1) * SS(1))/100 \quad (4)$$

where SS(1) is the state variable representing "effective" leaf area

index. Generally speaking, "effective" LAI is the same as LAI, but after defoliation it may differ from real LAI. This will be explained in the description of the INSECT subroutine.

Equation (4) was derived from light interception readings made when the plants were 6 or more weeks of age and cannot be used for younger plants, as it has a Y-intercept of 0.11767; i.e., plants with zero leaf area intercept nearly 12% of the incident radiation, according to this equation. Light interception for young plants was assumed to equal LAI, or,

$$PLTLAI = SS(1) \qquad (5)$$

until an LAI of 0.16. (Equations (4) and (5) intersect at an LAI of 0.16.) In essence this assumes that in young plants all leaves are fully exposed to the light with no shading. When the LAI is above 0.16, shading causes light interception to be lower than LAI. I changed PTSFAC in equation (1) from the 1.05 used for Florunner in PENUTZ to 1.10 to correct for the fact that the maximum value for PLTLAI in equation (4) is about 0.95 rather than the 1.00 maximum for PLTLAI used in PENUTZ.

The amount of photosynthate going to any one plant is calculated by dividing the plant's leaf area by the total leaf area/m^2. For the purpose of calculating leaf area index and thus light interception and photosynthesis, leaves are not counted as leaves until they are fully grown. Not until a leaf has completed development is its area computed by dividing its weight by the specific leaf weight of new leaves at that point in the season. Specific leaf weight is 4.98 until physiological day 40 (calendar day 34), 3.77 from day 41 to day 82 (calendar day 68), and 3.28 for the remainder of the season. These were the

average specific leaf weights for weeks 3-5, 6-10, and 11-16 (excluding week 14), respectively (Table 3). These specific leaf weights are used for defoliated as well as non-defoliated plants.

Division of Day's Net Photosynthate

The amount of carbohydrate allocated to the roots each day for root growth and nitrogen fixation depends on time in the growing season. The roots receive 15% of the day's net photosynthate for nitrogen fixation for the first 82 physiological days, and 13% thereafter. The additional amount allocated for root growth is 28% until week 4, 15% from week 4 until week 7, and 0% thereafter. The decision to allocate 15% to roots from week 4 until week 7 for root growth rather than the lower amount indicated in Table 24 was based on balancing top growth during this time period against photosynthetic supply. Allocating at least 12% of the net carbohydrate to roots for nitrogen fixation prevents any nitrogen shortage from occurring, if 100% efficiency of conversion is assumed.

The remainder of each day's photosynthate is apportioned according to demand from leaves, stem internodes, seeds, and expanding pods. Leaf demand for carbohydrate is based on the number of developing leaves and the amount each leaf can add on a given day. Demands for the attached petiole and internode are also calculated and included in the leaf demand variable, WANTLF. Maximum new leaf size is set at 88 mg, the average weight per leaf for new leaves for weeks 6 - 10 (Table 3). Leaves grow for either 10.8 or 14.4 physiological days, depending on the point in the season, and thus leaves and petioles only demand carbohydrate for that length of time. Stem internodes continue to

Table 24. Root growth during the 1978 growing season, as indicated by weekly plant samples.

Week from Planting	Root Weight, g/m^2	Root Growth as % of Total Plant Growth
3	1.3	25.3
4	3.3	28.1
5	4.2	7.0
6	5.3	2.2
7	12.2	9.2
8	17.7	11.4
9	11.5	--
10	13.1	--

grow and demand carbohydrate until 32.4 physiological days (27 calendar days) after initiation.

Shell demand is calculated according to the formula

$$WANT = (10.0 + 0.25 * PODWGT(J,K)) * DAYINC \qquad (6)$$

where PODWGT(J,K) is the weight of an individual pod initiated on day K on plant J and DAYINC is the number of physiological days in the given calendar day. About 85% of this demand is for carbohydrate (McGraw 1977). When the pod reaches 17% of its capacity it is considered to be fully expanded and shell growth stops and seed growth begins. If there is no shortage of carbohydrate it takes approximately 8 calendar days for the first pods to become fully expanded.

In this model, as in PENUTZ, pods that are filling seeds may grow at a maximum rate of 22 mg/physiological day. Since more energy is expended in making kernels than in making other plant parts, 35.9 mg of carbohydrate are required to produce this 22 mg of kernel dry weight. This is a result of the higher oil and protein concentration in seeds than in other plant parts (McGraw 1977). Each developing pod that is filling seeds thus demands 35.9 mg/day until it reaches 80% of its capacity. It then continues to grow at half this rate until fully grown. Schenk (1961) noted that pod growth rate declines in the later stages of seed enlargement. In both PMINUS and PENUTZ, the later in the season a pod is initiated, the smaller is its capacity.

If there is a surplus of carbohydrate after all growth demands are filled on any day, then the excess is sent to stems for storage. If there is a shortage, then allocation of the available photosynthate is determined on a priority basis. The system of priorities is based

partially on canopy LAI, as an indicator of light interception. Developing seeds have priority over all other plant parts, and after podset, they may draw from stem storage, if necessary, to fill their demands. This is based on my own field results and the observations of Hang An (1978) who performed plant shading experiments. There is a limit to the amount of photosynthate which seeds assimilate on any day. In PMINUS, this limit is 65% of the day's net photosynthate or, after podset, 65% of the maximum 5-day-average net photosynthate. Thus, once the pod load is set, pods may get more than 65% of the day's net photosynthate if it is less than the maximum 5-day-average. In PENUTZ, a maximum was set in a similar manner on amount of photosynthate allocated to all pods, rather than to seeds. On any day when there is insufficient carbohydrate available for seeds to satisfy total seed demand, priority is given to older pods.

If the effective LAI (ELAI) is less than 2.5, then developing leaves and their attached petioles and internodes have priority over all plant parts except seeds. If ELAI is less than 2.0, the leaves which are more than half-grown may draw from stem storage, if necessary, to meet their demands. If there is excess carbohydrate after leaf demand is met (ELAI < 2.5), then the initiation of new vegetative branches has next priority.

Early in the season (before LAI reaches 0.16 for the first time) vegetative growing points become active automatically without carbohydrate and nitrogen availability being taken into account. Once LAI reaches 0.16 for the first time, growing points are initiated only if there is excess carbohydrate left after root, seed, and leaf demands

are filled. The model keeps track of potential new growing points each day and each one is allowed 3 days to be activated. If there is insufficient photosynthate to activate it within this time, then it is relegated to the permanently inactive file of growing points. Once there are 333 vegetative branches, no new growing points may become active, except in the event of severe defoliation. Growing point initiation is cut off when ELAI reaches 2.5, even if there are fewer than 333 vegetative branches.

Any carbohydrate left after new branches are initiated goes to meet stem internode and expanding pod demand. When ELAI is above 2.5, any shortage in carbohydrate supply is allocated uniformly to leaves, stems, and expanding pods. Older pods have priority over younger ones, although PENUTZ and PMINUS are set up so that older pods can be given from 0 to 100% priority.

PENUTZ was structured so that if a nitrogen shortage occurred, at any time, the rest of the day's carbohydrate supply would be allocated to the roots to fix nitrogen. This feature was retained in PMINUS, but the amount of carbohydrate allocated to roots is set sufficiently high that a nitrogen shortage never occurs.

Calculation of Increases in Total Dry Weight per Unit of Carbohydrate

The ratio of carbohydrate to nitrogen and the proportion of total weight which is either carbohydrate or nitrogen are different for different plant structures. In PENUTZ, Duncan assumed that 12% of leaf, stem, and shell dry weights was protein, 85% was carbohydrate, and 3% was other constituents. For nuts he assumed that 25% of total dry weight was protein, 50% was oil, 20% was carbohydrate, and 5% was

other constituents. He further assumed that it required 2.85 units of carbohydrate to produce 1 unit of oil. The same assumptions are made in PMINUS.

Once the amount of carbohydrate available for leaf, stem, or shell growth on a given day has been calculated, the total dry weight added to that portion of the plant is calculated by

$$\frac{dW_v}{dt} = \left(\frac{dC_v}{dt} + \frac{dN_v}{dt}\right) / 0.97 \tag{7}$$

where dC_v/dt is the change in carbohydrate for the given plant structure, dN_v/dt is the change for nitrogen, and the subscript v refers to either leaf, stem, or shell. The amount of nitrogen needed is calculated by assuming a nitrogen:carbohydrate ratio of 12:85.

For nut growth, the total dry weight added on a given day is calculated by the equation

$$\frac{dW_n}{dt} = \left(\frac{dC_n}{dt} + \frac{dO_n}{dt} + \frac{dN_n}{dt}\right) / 0.95 \tag{8}$$

where dC_n/dt is the weight of carbohydrate added to nuts, dO_n/dt is the weight of oil, and dN_n/dt is the weight of nitrogen in the form of protein. The ratio of carbohydrate:oil:nitrogen used is 20:50:25, and 2.85 units of carbohydrate are used to produce 1 unit of oil.

Inactivation of Vegetative Growing Points

The cessation of active growth by any branch is controlled by time in the growing season and the size of the last leaf on the branch. No stem may stop growing until after day 82, when leaf development time is increased from 10.8 to 14.4 days. Maximum leaf size remains 88 mg, but daily demand/leaf is reduced at this point due to the increased

development time. Lack of sufficient carbohydrate to meet total demands from pods, stems, and leaves on any given day may result in leaves that are smaller than the maximum size. After day 82, the weight/leaf of all leaves completing development on day K is checked against SIZMIN (70.0 mg). If WTLEAF(J,I), the weight of a single leaf initiated on day I on plant J, is greater than SIZMIN, then no growing points are inactivated. If WTLEAF(J,I) is less than SIZMIN, growing points are shut down in the proportion of WTLEAF(J,I)/SIZMIN; i.e., the smaller the leaves that are just completing development, the greater the number of growing points which are shut down.

Cessation of Peg and Pod Initiation

Reproductive nodes continue to be activated and pegs continue to grow until the time the pod load is set. This point is reached when seeds have demanded more photosynthate than is available to them for 5 days. When this occurs, flowering ceases and all pegs which have not developed to the point that they can expand as pods (i.e., they are less than 27.0 physiological days old) are removed from the system. On any day from the time the first pod starts to swell until podset, no new reproductive nodes are activated if there is no photosynthate available on that day for stem growth and pod expansion. This was based on the observation by Hang An (1978) that 75% shade (and the resulting shortage of photosynthate) reduced flowering and reduced peg formation after 7 days.

If a peg has not started swelling (i.e., its weight is still zero) after 32 physiological days as a potential pod, then it is deleted from

the system. A shell that is not fully expanded after 42 physiological days ceases to grow and make demands for carbohydrate.

INSECT Subroutine

INSECT is the subroutine developed to link PMINUS to an insect development model. Each day that simulated insect damage occurs, it is called to compute changes in leaf weight and area and in canopy light interception due to defoliation. The type of defoliation must be specified. At present, INSECT can simulate the effects of 3 types of defoliation: 1) removal of the same proportion of leaf material from each leaf on the plant; 2) removal of whole leaves, starting with the youngest; and 3) removal of portions of leaves as in 1) plus removal of some or all of the active vegetative growing points on the plant. Only minor changes would be required to combine leaf removal as in 2) with removal of growing points.

The effect of defoliation on canopy light interception and photosynthesis is handled differently in the model depending on the type of defoliation. The data collected by Jones et al. (1980 and personal communication) were used to estimate the effect of uniform defoliation on photosynthesis. The regression line

$$Y = 99.45 - 0.0715 * \mathrm{DEFPER} - 0.00816 * \mathrm{DEFPER}^2 \qquad (9)$$

with an R^2 value of 0.96 relates DEFPER, percent defoliation, to Y, percent of photosynthesis of defoliated versus non-defoliated plants. (For the purposes of the regression, only readings that were made 1-3 days after defoliation or that were made after week 15, when leaf growth had essentially stopped, were used.) For example, a plant which is defoliated 50% on a given day will have, immediately after

defoliation, a photosynthetic rate 75.48% of its rate before defoliation, according to the equation. This value (Y) is multiplied by PLTLAI (proportion of the available light intercepted by the canopy prior to defoliation) to find the effective canopy light interception (Y'). This value (Y') is then inserted into equation (4) to find the normal canopy LAI which photosynthesizes at the same rate as the defoliated plants now do. This becomes the "effective" LAI for the defoliated plants and is used as the baseline for any increases or decreases in LAI in the future. Going back to the example of the plants defoliated 50% on a given day, if the plants had an LAI of 2.15 and were intercepting 60% of the available light just prior to defoliation, then they would now intercept 45.28% of the available light (75.48 * 0.60) and have an effective LAI of 1.39. In actuality, the LAI is half of 2.15, or 1.08, but these plants are photosynthesizing at the same rate as normal, non-defoliated plants with an LAI of 1.39. In summary, effective LAI is a variable to relate percent interception of defoliated canopies to percent interception of non-defoliated canopies.

The removal of leaves from the outer portion of the canopy was equated with removal of the youngest leaves. Since there were no data to relate light interception by plants defoliated in this manner to rate of photosynthesis, the assumption was made that the photosynthetic rate of plants defoliated in this manner is the same as the photosynthetic rate of non-defoliated plants with an LAI equal to the reduced LAI. For example, if 50% of the total leaf area is removed in this manner from a plant with an initial LAI of 3.0, then, after treatment, the plant will photosynthesize at the same rate as a normal plant with an LAI of 1.5. By removal of the outer envelope of leaves from the

canopy, the canopy is effectively returned to the size of a normal canopy with the lower LAI, as photosynthesis by bare stems is negligible (Jones et al. 1980).

If the level of defoliation is severe enough that percent light interception is reduced by more than 40% from its level when INSECT is first called, new vegetative growing points may be initiated, if there are any potentially active ones present. These growing points are of a special type in that they may only grow 1 leaf before shutting down. I assume that the normal maximum number of active growing points is $333/m^2$ and that only when stems are exposed to light may this number be temporarily exceeded until the canopy closes over again. The selection of 40% as the trigger point for this reaction was based on the fact that the 50% uniform defoliations (which reduced light interception by 25%) caused no increase in vegetative growing points, whereas the literature indicates (Mangold 1979, Williams et al. 1976) that 75% defoliation (50% decrease in light interception) resulted in increased leaf growth, which was probably due to an increase in the number of growing points.

If growing points are destroyed, then the last 2 nodes on the affected branch are checked to determine if they are vegetative or reproductive. If either of them is vegetative, then a new branch is initiated to replace the one destroyed.

Subroutine ATTAC

This is the subroutine which simulates insect entry into the system. It may do nothing more than call the subroutine INSECT on a given day to remove a certain portion of the leaves on that day, or it may be considerably more complicated.

Each of the defoliation experiments was simulated by calling INSECT on the day the plants were defoliated, and by specifying the percent and type of defoliation. For the simulations of removal of leaves from the outer portion of the canopy, a sufficient amount of defoliation was specified to bring the simulated LAI down to the same level as that of the experimental plants after treatment.

I also simulated defoliation experiments performed by Mangold (1979) in a field adjacent to mine. His peanuts were planted 1 or 2 days earlier than mine but the plant spacing and crop management were identical. The defoliations simulated were as follows:

1. 75% uniform at week 8
2. 75% uniform at week 8 plus 75% defoliation of new leaves for the next 7 days
3. 75% uniform at week 11
4. 75% uniform at week 11 and 75% defoliation of all new leaves at week 15.

In order to demonstrate the coupling of PMINUS to an insect development model, I constructed a simplistic model of an insect cohort entering the system, growing and eating for a certain number of days, and then leaving the system. One of the power curves derived by Huffman (1974) for consumption of peanut foliage by the bollworm, Heliothis zea (Boddie) was used in calculation of leaf material eaten each day:

$$Y = 0.011 * X^{2.995} \quad (10)$$

where X is the age of the larva in days and Y is the cumulative foliage consumption to date, in cm^2. I assumed all larvae emerged on the same day; the same number attacked each plant; they grew and fed for 26 days;

no mortality occurred; and they all left the system after 26 days. The simulated attacks were as follows:

1. 10 larvae per plant, entering the field on day 21, and feeding randomly on the plant (the effect of this on light interception was assumed to be the same as uniform defoliation)
2. 10 larvae per plant, entering the field on day 21, and feeding on the youngest leaves
3. 10 larvae per plant, entering the field on day 35, and feeding randomly on the plant
4. 10 larvae per plant, entering the field on day 35, and feeding randomly
5. 10 larvae per plant, entering the field on day 56, and feeding randomly
6. 10 larvae per plant, entering the field on day 56, and feeding on the youngest leaves
7. 20 larvae per plant, entering the field on day 35, and feeding randomly
8. 20 larvae per plant, entering the field on day 35, and feeding on the youngest leaves.

Results and Discussion

Comparison of Model Predictions with Growth of Non-defoliated Plants in the Field

Figures 2 through 9 are graphs of time versus LAI, number of leaves, leaf dry weight, stem dry weight, number of pods, pod dry weight, number of fully expanded pods (P4's and P5's), and weight of fully expanded pods, according to the weekly plant samples and according to the

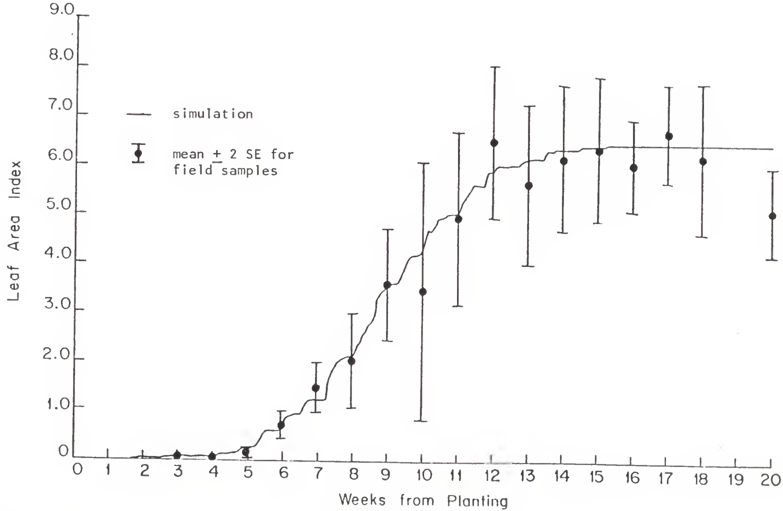


Figure 2. Simulated and experimental leaf area index for Florunner peanuts planted on 24 May 1978.

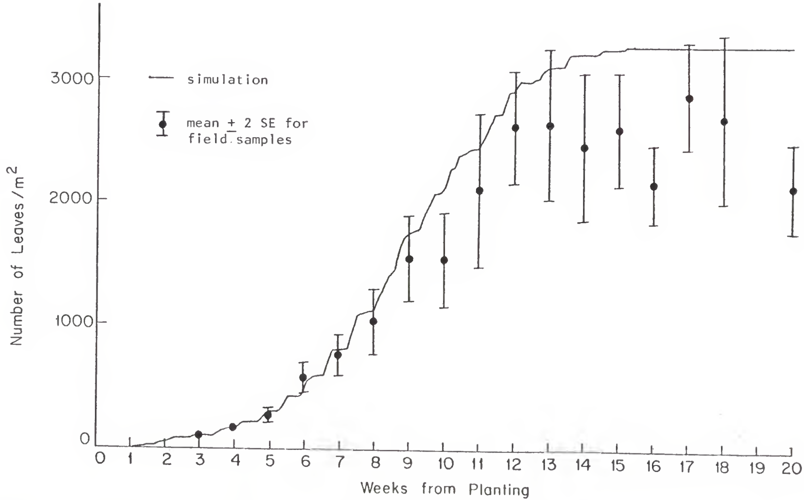


Figure 3. Simulated and experimental change in leaf numbers for Florunner peanuts planted on 24 May 1978.

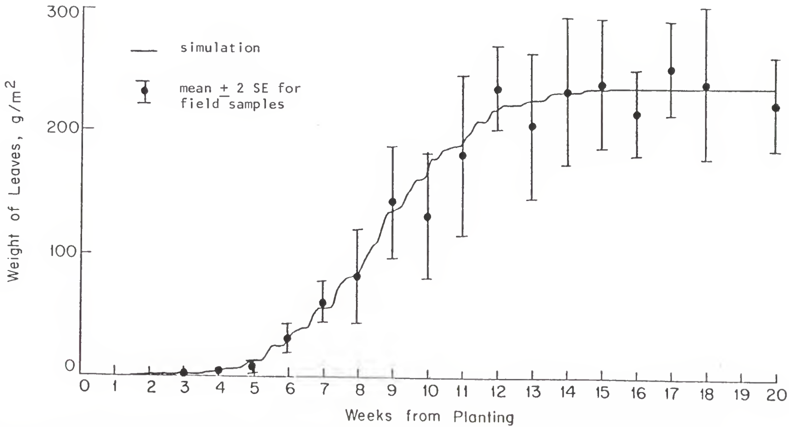


Figure 4. Simulated and experimental leaf growth for Florunner peanuts planted on 24 May 1978.

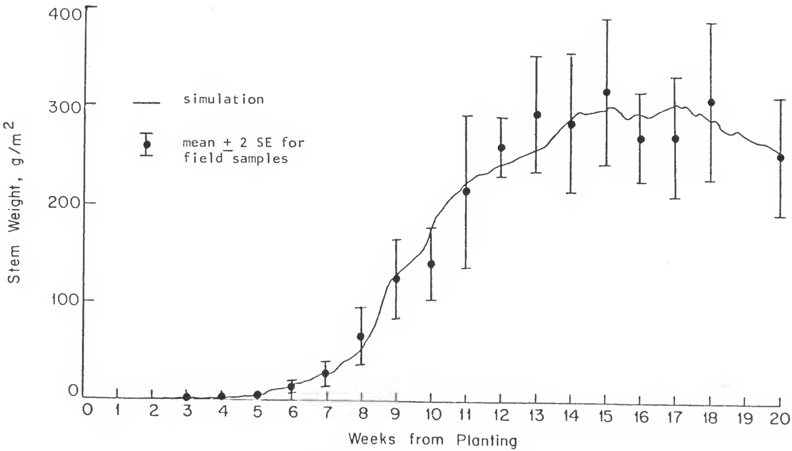


Figure 5. Simulated and experimental stem growth for Florunner peanuts planted on 24 May 1978.

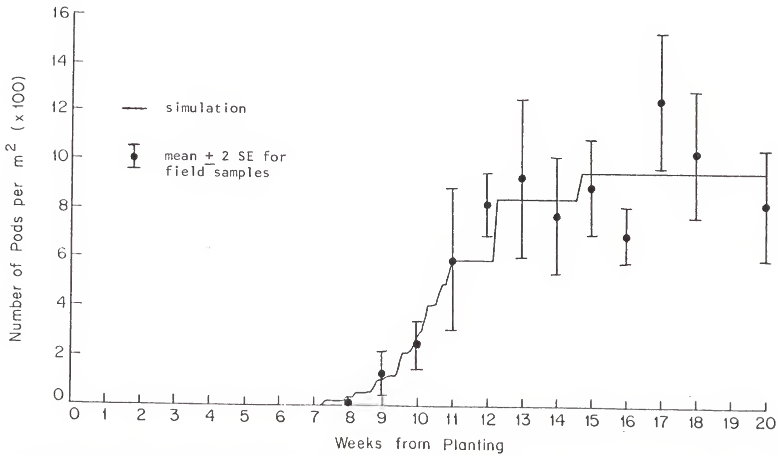


Figure 6. Simulated and experimental changes in pod numbers for Florunner peanuts planted on 24 May 1978.

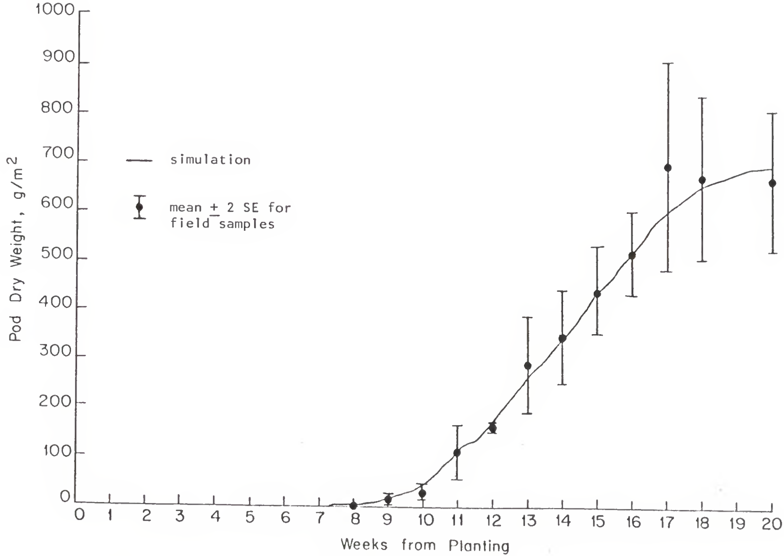


Figure 7. Simulated and experimental pod growth for Florunner peanuts planted on 24 May 1978.

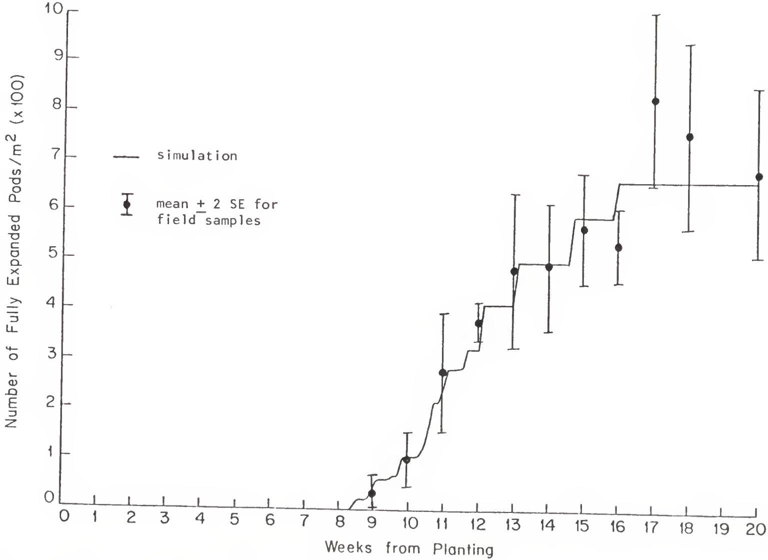


Figure 8. Simulated and experimental change in number of fully expanded pods for Florunner peanuts planted on 24 May 1978.

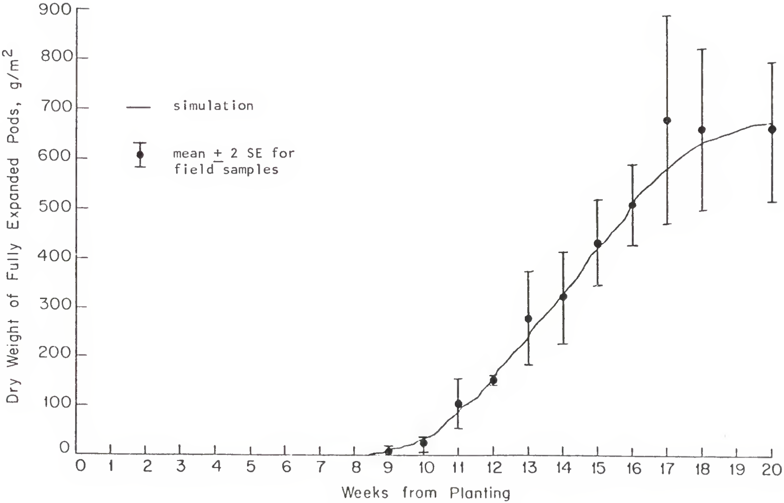


Figure 9. Simulated and experimental growth of fruit filling seeds for Florunner peanuts planted on 24 May 1978.

model predictions. For all variables the average plant means from the weekly sampels were converted to a square meter basis by multiplying by 9.5 plants/m^2. Simulated leaf, stem, and pod dry weights are within the 95% confidence intervals for the experimental means at all times during the season.

Simulated and experimental leaf area indexes match until the very end of the season, when LAI of the field plants declines, but that of the model plants does not. Rather than model leaf loss, I chose to use the results of Jones et al. (1980), obtained in a plot adjoining mine, to model the decrease in gross photosynthesis late in the season. They noted a 40% drop in P_{1500} (gross photosynthesis at a light intensity of 1500 $\mu E/m^2$) between weeks 17 and 19; a drop that was due to the combined effects of decreased LAI and decreased efficiency of aging leaves.

The fact that the model does not deal with loss of leaves due to age or stress conditions leads to another difference between simulation and field results, as shown in Figure 3. Number of leaves/m^2 is overestimated by the model after week 7 since at this point in the season plants in the field started to lose leaves. The model does a fairly good job of matching field results for the growth of new leaves each week (Table 25), except between weeks 8 and 9. Simulated leaf weight and LAI match those of the sample plants because the model adds less weight to new leaves many weeks than do the sample plants (Table 25). If leaf loss were to be included in the model, it would be necessary to increase the photosynthate available for vegetative growth to account for the extra leaf weight.

There are 3 points in the season when simulated pod numbers do not correspond to those of the sample plants--at weeks 12, 16, and 17

Table 25. Comparison of leaf growth in the field with model predictions.

Period of Time, Weeks from Planting	No. of New Leaves/m^2 Field	No. of New Leaves/m^2 Model	Wt. of New Leaves, g/m^2 Field	Wt. of New Leaves, g/m^2 Model
0 - 3	102.6	104.5	2.1	1.9
3 - 4	70.3	47.5	2.0	2.0
4 - 5	112.1	142.6	5.6	9.0
5 - 6	228.0	142.5	18.5	13.1
6 - 7	346.8	370.6	34.4	30.3
7 - 8	397.1	323.1	31.9	26.7
8 - 9	482.6	627.2	47.3	53.5
9 -10*	291.6	370.6	24.5	28.9
10 -11	337.2	332.6	24.3	20.6
11 -12	475.0	465.7	32.9	28.5
12.-13	196.6	199.5	14.0	8.4
13 -14	196.6	114.1	15.0	6.8
14 -15	28.5	38.0	1.4	2.8
15 -16	31.4	19.0	1.9	1.0
16 -17	2.8	0.0	--	--

*Leaves were marked 2 days late this week, so this is the number and weight of leaves grown in a 5-day period.

(Figure 6). The difference at week 17 can probably be explained by the small sample size (3 plants). I cannot explain the difference at week 16. There were 15 plants in the sample, but for some reason they were smaller than average, as indicated by pod number, leaf number, and leaf and stem weight. The difference at week 12 is probably due to the way photosynthate is distributed in the model. The stepwise increase in pod numbers after week 11 is due to the fact that in the model available carbohydrate is distributed to expanding pods on an oldest-first basis. Only on a day when radiation and photosynthesis are extremely high is there sufficient carbohydrate left over, after the demand of existing pods is met, to initiate new pods. Distribution of photosynthate may not be quite so cut and dried in reality. Giving 100% priority to the oldest fruits does result in a good correspondence between field and model of number and weight of fully expanded pods (Figures 8 and 9).

Comparison of Model Predictions with Results of the Field Defoliations

Table 26 is a summary of plant growth in the 2½ weeks following defoliation at week 4½, as indicated by model simulation and by the field experiment. There was a large amount of variation between treatments in the average LAI just prior to defoliation. This variation seemed to affect the model's ability to simulate the effect of defoliation on leaf growth. The closer the initial LAI of the field plots was to the initial model LAI of 0.14, the closer was the correspondence between field and simulated LAI and leaf weight at harvest. The model underestimated the stem weight at harvest for the control plants and for the plants which were defoliated 50% and 100%. Otherwise, model and field stem weights matched well except for the plants from

Table 26. Comparison of model predictions with field results for plants defoliated at $4\frac{1}{2}$ weeks and harvested at 7 weeks.

Treatment	Initial LAI		LAI after Defoliation		LAI at Harvest		Leaf Weight at Harvest, g/m^2	
	Field*	Model	Field*	Model	Field*	Model	Field*	Model
Check	0.14 (0.02)	0.14	0.14 (0.02)	0.14	1.42 (0.17)	1.42	56.7 (7.1)	56.2
25% uniform	0.10 (0.02)	0.14	0.08 (0.01)	0.10	1.07 (0.15)	1.36	42.0 (5.8)	55.2
50% uniform	0.16 (0.02)	0.14	0.08 (0.01)	0.07	1.32 (0.17)	1.27	51.7 (6.5)	51.3
100%	0.15 (0.02)	0.14	0.00 (0.00)	0.00	0.90 (0.15)	0.93	32.7 (5.0)	35.9
0% + veg. growing points	0.22 (0.03)	0.14	0.22 (0.03)	0.14	0.97 (0.14)	0.79	36.4 (4.8)	31.6
50% + veg. growing points	0.14 (0.02)	0.14	0.07 (0.01)	0.07	0.59 (0.08)	0.63	23.6 (3.1)	24.7
100% + veg. growing points	0.20 (0.03)	0.14	0.00 (0.00)	0.00	0.25 (0.04)	0.10	9.3 (1.4)	3.8

*Number in parentheses is standard error of the mean.

Table 26. Continued

Treatment	Weight of New Leaves, g/m2		Stem Weight, g/m2		Gain in Stem Weight, g/m2		Number of New Leaves per m2	
	Field*	Model	Field*	Model	Field	Model	Field*	Model
Check	49.8 (6.3)	49.4	38.2 (5.2)	27.6	35.2	24.7	686.0 (61.1)	598.6
25% uniform	37.1 (5.0)	49.9	27.0 (4.3)	26.7	24.2	23.8	545.3 (44.6)	589.1
50% uniform	47.5 (6.1)	47.8	33.1 (5.1)	25.2	29.4	22.3	583.3 (56.6)	579.6
100%	32.7 (5.0)	35.9	21.7 (3.4)	17.8	18.1	14.8	513.7 (53.1)	589.1
0% + veg. growing points	28.1 (4.0)	24.8	23.7 (3.8)	24.1	20.1	21.2	499.7 (49.7)	285.0
50% + veg. growing points	19.8 (2.6)	21.3	15.5 (2.1)	15.8	12.3	12.9	432.0 (40.2)	285.0
100% + veg. growing points	9.3 (1.4)	3.8	8.8 (1.2)	4.3	4.0	1.4	309.7 (28.8)	285.0

*Number in parentheses is standard error of the mean.

which all leaves and all vegetative growing points were removed. In this case the model underestimated leaf growth as well. It may be that the plants in the field were able to draw some carbohydrate from stems to make leaves. In the model, leaf and stem demands are so high in comparison to available photosynthate that there is no storage of carbohydrate in the stems until week 8.

The simulated number of new leaves initiated after treatment was within the confidence interval ($\pm$ 2 SE) for the experimental mean except in the case of plants defoliated 0 or 50% from which the vegetative growing points were removed. This can probably be attributed, at least in part, to a failure to remove all of the small new leaves beginning in the axils of fully grown leaves.

Tables 27 and 28 are comparisons of field results and model predictions for plants defoliated at week 9. Figures 10 and 11 are graphical representations of the comparisons for LAI and pod dry weight. The simulated values for all plant variables are within the 95% confidence intervals for the experimental means except for the number of pods at 15 weeks on plants from which all the leaves were removed from the outer half of the canopy. In this case simulated pod weight was also somewhat higher than the experimental mean, but it was well within the confidence interval. For this experiment there was a good correspondence generally between simulated and field results in weight of new leaves and gain in stem weight.

Comparisons of model predictions with field results of the week 12 defoliation are summarized in Tables 29 and 30 and Figures 12 and 13. There is again some problem with matching number of pods/m^2.

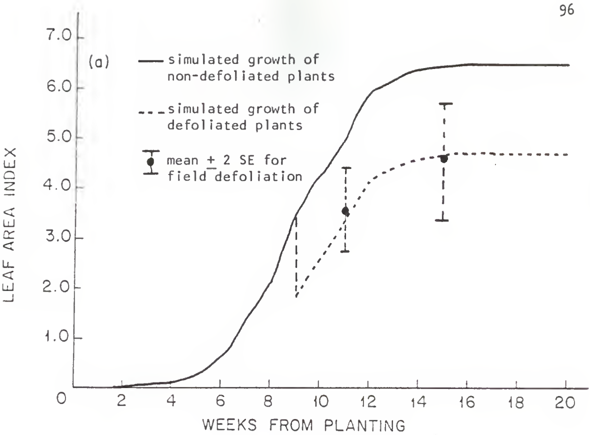
Table 27. Comparison of model predictions with field results for plants defoliated at 9 weeks and harvested at 11 weeks.

Plant Variable	Treatment					
	Control		50% Uniform		Outer 50% of Canopy	
	Field*	Model	Field*	Model	Field*	Model
Original LAI	4.0 (0.9)	3.6	4.6 (0.7)	3.6	4.3 (0.5)	3.6
LAI after defoliation	4.0	3.6	2.0	1.8	1.2	1.3
LAI at harvest	5.2 (1.1)	5.1	3.6 (0.4)	3.3	3.4 (0.3)	3.1
Leaf weight at harvest, g/m^2	188.9 (40.1)	189.9	126.2 (15.3)	121.7	119.5 (11.0)	112.8
Weight of new leaves, g/m^2	41.7 (6.3)	53.5	50.4 (5.0)	51.1	66.1 (6.1)	61.6
Stem weight, g/m^2	212.4 (47.3)	221.9	213.4 (33.5)	192.4	218.0 (27.8)	162.8
Gain in stem weight, g/m^2	85.3	92.9	67.0	63.8	43.8	35.4
Number of pods/m^2	656.4(173.7)	598.7	697.6(121.0)	598.7	562.9 (64.3)	598.7
Weight of pods, g/m^2	118.1 (33.2)	109.0	91.5 (18.3)	100.2	70.3 (11.4)	79.2
Number of P4-P5/m^2	286.7 (72.4)	237.6	215.0 (44.4)	285.1	201.1 (25.8)	161.6
Weight of P4-P5, g/m^2	112.3 (31.4)	87.5	81.5 (17.4)	89.1	62.6 (17.5)	57.2

Table 28. Comparison of model predictions with field results for plants defoliated at 9 weeks and harvested at 15 weeks.

Plant Variable	Treatment					
	Control		50% Uniform		Outer 50% of Canopy	
	Field*	Model	Field*	Model	Field*	Model
Original LAI	4.4 (0.6)	3.6	4.1 (0.7)	3.6	3.5 (0.4)	3.6
LAI after defoliation	4.4	3.6	2.0	1.8	1.2	1.3
LAI at harvest	7.0 (0.9)	6.5	4.6 (0.6)	4.7	4.3 (0.3)	4.3
Leaf weight at harvest, g/m^2	257.1 (31.8)	236.3	183.5 (23.6)	166.5	157.8 (12.2)	154.5
Weight of new leaves, g/m^2	108.2 (12.1)	99.9	108.2 (13.9)	95.8	113.9 (9.1)	103.3
Stem weight, g/m^2	345.7 (43.9)	298.3	272.1 (40.2)	278.6	243.6 (24.8)	249.0
Gain in stem weight, g/m^2	210.0	169.3	143.1	150.0	114.0	120.4
Number of pods/m^2	960.4(117.1)	959.8	781.1(141.8)	826.7	682.9 (61.2)	826.7
Weight of pods, g/m^2	479.4 (51.9)	435.2	394.4 (54.7)	412.4	354.0 (35.1)	379.4
Number of P4-P5/m^2	594.2 (69.8)	598.7	522.5 (68.6)	598.7	492.9 (47.9)	503.6
Weight of P4-P5, g/m^2	469.6 (50.1)	422.6	388.6 (53.3)	405.1	349.6 (34.4)	360.6

*Number in parentheses is standard error of the mean.



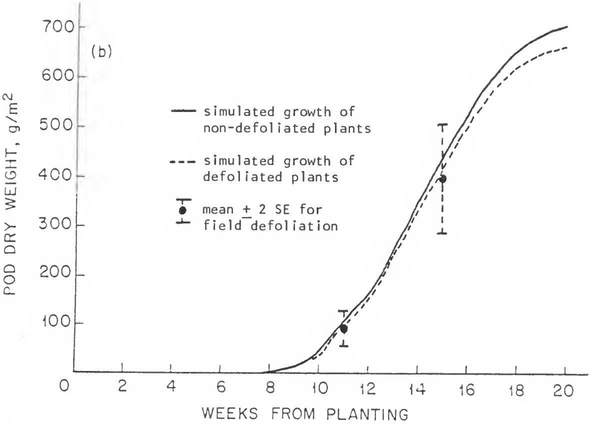


Figure 10. The simulated and experimental effect of 50% uniform defoliation at 9 weeks after planting on LAI (a) and pod dry weight (b).

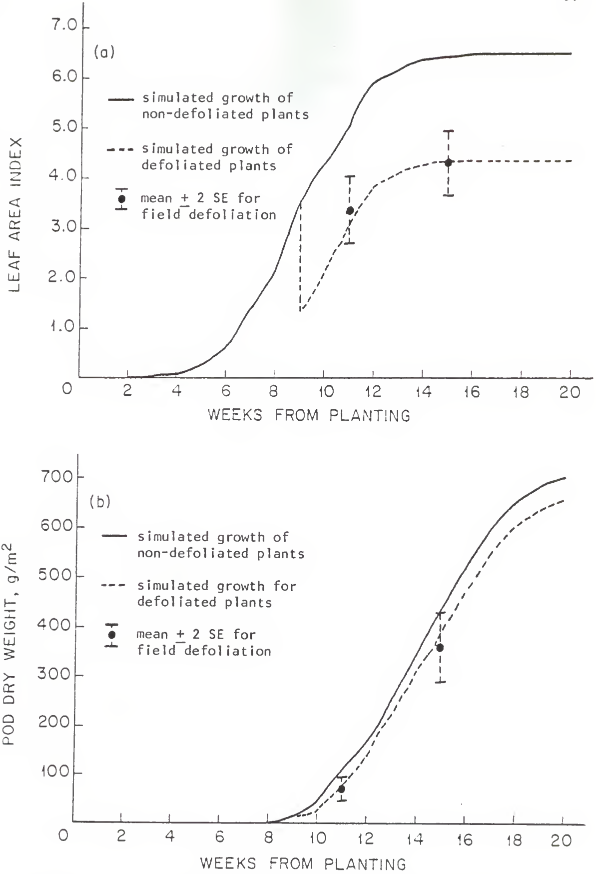


Figure 11. The simulated and experimental effect of removal of all leaves from the outer 50% of the canopy at 9 weeks after planting on LAI (a) and pod dry weight (b).

Table 29. Comparison of model predictions with field results for plants defoliated at 12 weeks and harvested at 14 weeks.

	Treatment					
	Control		50% Uniform		Outer 50% of Canopy	
Plant Variable	Field*	Model	Field*	Model	Field*	Model
Original LAI	5.6 (0.9)	5.9	6.1 (0.9)	5.9	6.7 (0.6)	5.9
LAI after defoliation	5.6	5.9	2.7	3.0	2.6	2.7
LAI at harvest	5.8 (0.9)	6.4	3.0 (0.5)	3.4	3.1 (0.3)	3.0
Leaf weight at harvest, g/m^2	216.6 (34.4)	233.5	122.3 (18.3)	121.8	116.3 (12.1)	114.5
Weight of new leaves, g/m^2	8.5 (1.2)	15.2	12.1 (2.4)	11.2	19.6 (3.0)	10.3
Stem weight, g/m^2	264.6 (41.3)	291.4	251.9 (38.2)	283.5	280.5 (34.4)	276.3
Gain in stem weight, g/m^2	49.8	49.6	25.2	42.7	8.5	35.5
Number of $pods/m^2$	708.5(135.8)	855.3	711.7(120.7)	598.7	897.0(101.2)	598.7
Weight of pods, g/m^2	340.3 (61.0)	343.3	335.6 (55.5)	293.2	349.7 (39.8)	287.9
Number of P4-$P5/m^2$	452.8 (74.3)	503.6	427.5 (68.4)	418.1	428.3 (55.0)	418.1
Weight of P4-P5, g/m^2	313.1 (58.2)	329.6	327.4 (54.3)	286.0	338.8 (38.7)	281.9

*Number in parentheses is standard error of the mean.

Table 30. Comparison of model predictions with field results for plants defoliated at 12 weeks and harvested at 16 weeks.

Plant Variable	Treatment					
	Control		50% Uniform		Outer 50% of Canopy	
	Field*	Model	Field*	Model	Field*	Model
Original LAI	5.6 (0.4)	5.9	5.8	5.9	5.0	5.9
LAI after defoliation	5.6 (0.4)	5.9	3.0 (0.3)	3.0	1.8 (0.3)	2.0
LAI at harvest	6.0 (0.5)	6.5	3.5 (0.3)	3.5	2.6 (0.3)	2.5
Leaf weight at harvest, g/m^2	213.1 (19.9)	237.3	123.2 (9.6)	125.7	101.9 (12.5)	93.6
Weight of new leaves, g/m^2	15.3 (2.6)	19.0	19.8 (2.7)	15.1	36.4 (3.7)	17.2
Stem weight, g/m^2	269.9 (25.9)	295.2	246.0 (24.1)	286.8	196.3 (23.2)	265.6
Gain in stem weight, g/m^2	79.5	53.4	33.4	46.1	0.5	24.8
Number of pods/m^2	729.1 (67.0)	959.8	795.2 (121.9)	826.7	654.6 (108.6)	598.7
Weight of pods, g/m^2	552.0 (45.5)	520.8	511.9 (53.1)	443.1	417.7 (57.0)	385.8
Number of P4-P5/m^2	558.1 (43.6)	674.7	549.3 (62.9)	598.7	411.1 (58.7)	503.6
Weight of P4-P5, g/m^2	546.0 (44.6)	511.2	505.9 (52.1)	439.6	362.9 (55.3)	383.6

* Number in parentheses is standard error of the mean.

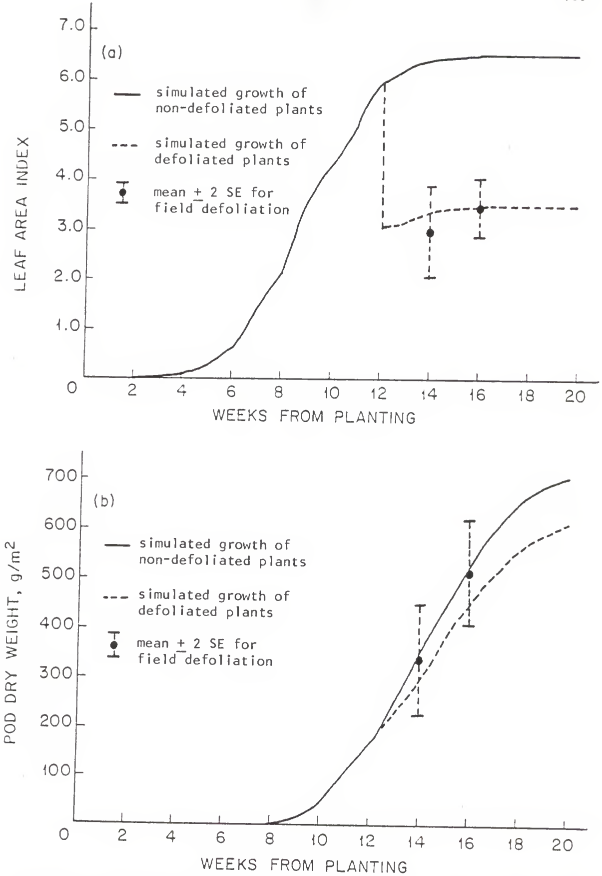


Figure 12. The simulated and experimental effect of 50% uniform defoliation at 12 weeks of age on LAI (a) and pod dry weight (b).

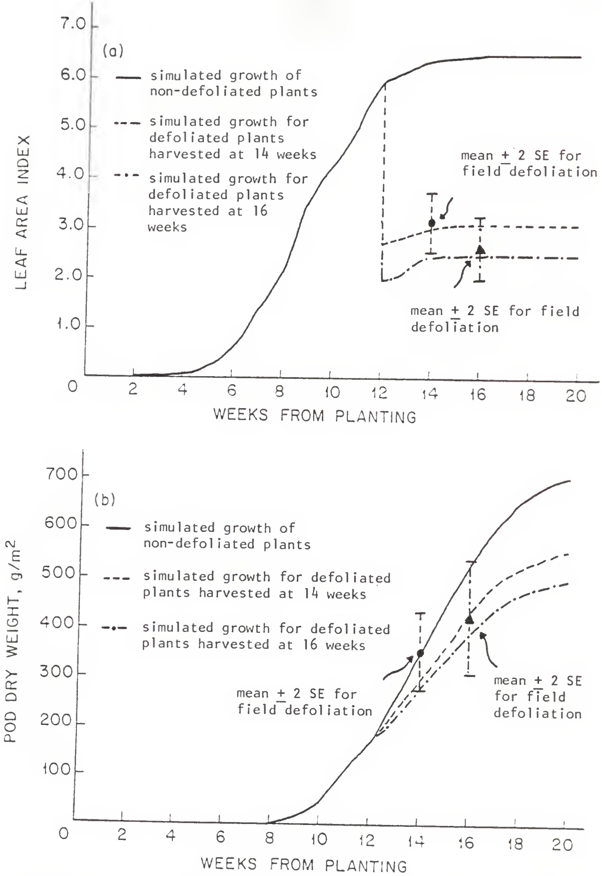


Figure 13. The simulated and experimental effect of removal of all leaves from the outer 50% of the canopy at 12 weeks of age on LAI (a) and pod dry weight (b).

There is a great deal of variability between plants in this respect. Also, the problem is perhaps partially due to the cut and dried method of allocating available photosynthate to oldest pods first. As pod dry weight/m^2 is usually well within the confidence limits for the experimental means, the difference in pod number between field results and model simulation is a difference mainly in number of small pods.

The model estimate of weight of new leaves/m^2 for the control plants is higher than the field average for plants marked at 9 weeks and harvested at 11 weeks (Table 27) and for plants marked at 12 weeks and harvested at 14 weeks (Table 29). This is due to a difference in the marking system for plants used as controls in the defoliation experiments as opposed to that for plants marked weekly for determination of weekly growth of leaves, as used in model development. In the defoliation experiments a leaf was marked if the petiole was sufficiently extended for a surgical wound clip to fit around it, whereas in the weekly plant markings a leaf was marked if the leaf above it was starting to unfold. When the plants were harvested, in both cases a leaf was included in the count of new leaves only if the leaf above it was starting to unfold. This had the effect of decreasing the number of new leaves per branch by one in the 2 weeks following marking in the defoliation experiments, as compared to the weekly plant samples. The difference in leaf weight between model and field control diminished in the following 2 or 3 weeks (Tables 28 and 30) due to the fact that the specific leaf weight and weight/leaf of leaves initiated after the field plants were marked increased as the leaves aged, whereas these remained constant in the model.

The weight of new leaves/m^2 is lower for the simulated removal of all leaves from the outer 50% of the canopy at 12 weeks than for the field experiment (Tables 29 and 30). This is due to the fact that in the model developing leaves may only draw carbohydrate from storage if the LAI is less than 2.0. Even though leaves have priority over stems and expanding pods if the LAI is below 2.5, at this point in the season there is a sufficient number of developing seeds to use all of the photosynthate produced by the defoliated plants on most days. It would appear from the differences in stem weight gains between the field experiment and the simulation that in actuality the plants can draw upon reserves to a greater extent than is allowed in the model. I used the 2.0 LAI limit for drawing upon stem storage because it worked well for the defoliation experiment at 9 weeks (Tables 27 and 28) and because higher limits caused the plants defoliated at 9 weeks in the simulated experiments to seriously overshoot the LAI of the field plants defoliated at 9 weeks and harvested at 15 weeks. In order to use the higher limit, which would work better at 12 weeks, it would be necessary to change the method of inactivating growing points in the model, making it dependent upon some factor other than the weight/leaf of the leaves completing development on a given day. The fact that the specific leaf weight and size of new leaves are essentially the same for the check and defoliated plants for the last 3 experiments (Table 31) indicates that once a leaf is initiated it gets as much photosynthate as it wants, if at all possible. Therefore, growing point inactivation should probably not be tied to leaf size. This is something which needs to be investigated further.

Table 31. Specific leaf weights and average size of new leaves grown in the 2 weeks following defoliation.

Defoliation Date, Week	Treatment Type	SLW* of New Leaves, mg/cm^2	Average Wt. per Leaf, mg	Average Area per Leaf, cm^2
9	Check	3.44	83.0	24.1
	50% uniform	3.34	93.5	28.0
	50% outer	3.46	80.2	23.2
12	Check	3.88	88.3	22.8
	50% uniform	4.25	84.2	19.8
	50% outer	3.66	64.7	17.7
16	Check	2.60	14.8	5.7
	50% uniform	4.09	20.8	5.1
	100%	3.45	17.6	5.1

*Specific leaf weight

Table 32 and Figure 14 are comparisons of model and field results for plants defoliated at 16 weeks and harvested 2 weeks later. Experimental and simulated results match well except for the weight of new leaves/m^2. The model plants have already shut down all vegetative growing points by week 16, whereas a few are still active on the field plants at 16 weeks.

The simulations of 4 of the defoliations performed by Mangold (1979) fit field results well in some respects and not so well in others (Tables 33 and 34). The model underestimated the weight of new leaves 2 weeks after treatment for the plants defoliated 75% (Table 33). According to the model there was little carbohydrate in stem storage at 8 weeks which could be drawn upon to grow leaves, but apparently in the field the plants were able to draw upon reserves to grow leaves. A more rapid increase in LAI during the first week following defoliation would yield a higher level of photosynthesis during the following week which could produce the higher stem and pod weights observed in the field at 10 weeks.

The model did a good job of fitting weight of new leaves for plants defoliated 75% at 8 weeks with 75% of new leaves removed for 7 days subsequently (Table 33). Simulated stem and pod dry weights at 10 weeks are low. The plants may have been larger than the simulated plants prior to defoliation, but I don't have the information necessary to determine whether this was the case.

The model underestimated the amount of damage to final yield done by the 75% defoliation at 8 weeks and the 75% defoliation plus new leaves for 7 days at 8 weeks (Table 34). This is probably due to the fact that in the simulations the defoliated plants were slower in

Table 32. Comparison of model predictions with field results for plants defoliated at 16 weeks and harvested at 18 weeks.

Plant Variable	Treatment					
	Control		50% Uniform		Outer 50% of Canopy	
	Field*	Model	Field*	Model	Field*	Model
Original LAI	6.2 (0.8)	6.5	6.9 (0.6)	6.5	5.8 (0.5)	6.5
LAI after defoliation	6.2	6.5	3.1	3.2	0.0	0.0
LAI at harvest	6.2 (0.8)	6.5	3.2 (0.3)	3.2	0.2 (0.1)	0.0
Leaf weight at harvest, g/m^2	241.5 (30.9)	237.3	127.5 (11.8)	121.6	5.7 (1.9)	0.0
Weight of new leaves, g/m^2	0.9 (0.3)	0.0	2.8 (0.7)	0.0	5.5 (1.9)	0.0
Stem weight, g/m^2	309.9 (40.5)	290.0	271.4 (29.7)	244.3	243.1 (27.0)	209.0
Gain in stem weight, g/m^2	-20.9	-5.1	-51.1	-51.0	-90.2	-86.4
Number of pods/m^2	1037.2(129.6)	959.8	874.8 (94.4)	959.8	802.2	959.8
Weight of pods, g/m^2	674.0 (83.6)	653.3	629.9 (57.7)	645.8	492.8 (77.5)	581.1
Number of P4-P5/m^2	767.8 (95.2)	674.7	665.8 (65.9)	674.7	522.5 (90.9)	674.7
Weight of P4-P5, g/m^2	667.0 (82.5)	637.0	621.4 (57.3)	636.4	484.2 (76.2)	571.6

*Number in parentheses is standard error of the mean.

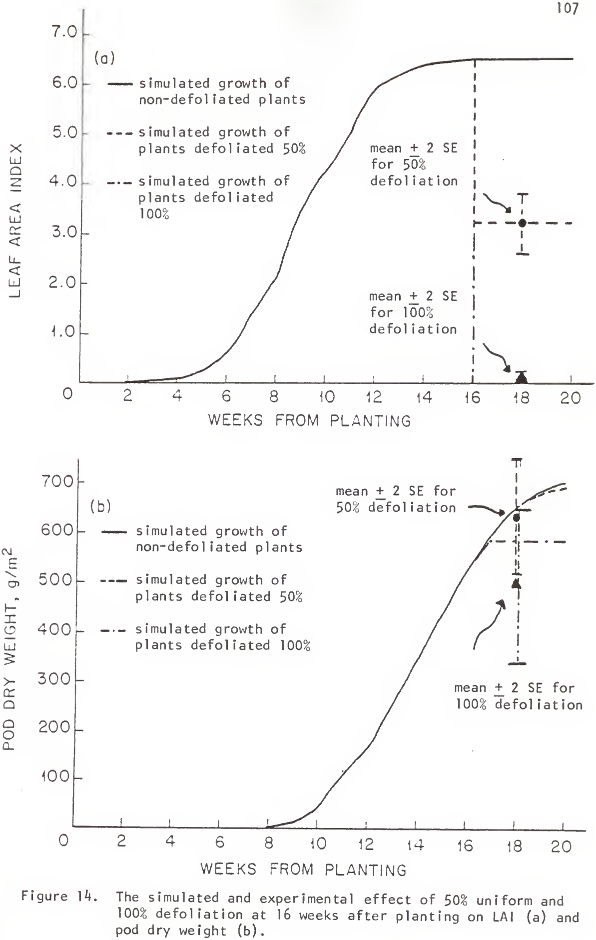


Figure 14. The simulated and experimental effect of 50% uniform and 100% defoliation at 16 weeks after planting on LAI (a) and pod dry weight (b).

Table 33. Comparison of simulated and experimental (Mangold, 1979) growth of Florunner peanuts in the 2 weeks immediately following defoliation at 8 weeks.

Treatment	Wt. of New Leaves, g/m^2		Wt. of Stems,* g/m^2		Wt. of Pods, g/m^2	
	Field	Model	Field	Model	Field	Model
Check	52.1	56.6	248.5	222.0	44.1	41.4
75% uniform	76.3	58.1	181.7	152.5	26.1	19.8
75% uniform + buds**	33.4	37.0	182.6	126.9	23.4	5.5

*Includes weight of leaf petioles.

**Buds removed for 7 days.

Table 34. Comparison of simulated and experimental (Mangold, 1979) yields for Florunner peanuts defoliated at various points in the season.

Treatment	Pod Dry Weight, g/m2		% Reduction in Yield	
	Field*	Model	Field	Model
Check	495.1a	460.9	--	--
75%, week 8	429.5ab	461.8	13	0
75% + buds, week 8**	365.4b	404.5	26	12
75%, week 11	349.0b	346.2	30	25
75%, weeks 11, 15	366.1b	346.0	26	25

*Values in the column followed by the same letter are not significantly different ($p < 0.05$), Duncan's new multiple range test.

**Buds removed for 7 days.

inactivating vegetative growing points than non-defoliated plants, with the result that final photosynthetic rates for defoliated and non-defoliated plants were almost equal. This was due to the mechanism used to determine growing point inactivation in the model. Further experiments need to be performed to determine the true mechanism for growing point inactivation.

The model predicted no difference in yield between plants defoliated only at 11 weeks and those defoliated at 11 weeks and again at 15 weeks, and this was in agreement with the field results (Table 34). The predicted level of yield reduction was also close to the actual amount.

Simulation of Insect Cohort Entering the Field

The simulations of an insect cohort entering the field at 3 different points in the growing season and at 2 different population levels indicate that the plants can tolerate larger infestations at some times than at others and that the location of feeding damage does make a difference. When 10 larvae/plant were introduced at 21 days after planting, the plants were destroyed. When the same number was introduced at 35 days post planting, no damage to final pod weight was sustained by plants on which feeding occurred randomly, whereas final pod weight was reduced by 6% when feeding was on the youngest leaves (Figure 15). Although LAI was essentially the same for the 2 types of feeding, effective LAI and consequently photosynthetic rate were higher for the plants defoliated randomly. When 10 larvae/plant entered the system at day 56 (feeding until day 82), the results were essentially the same as those for entry at day 35--less than 1% reduction in final

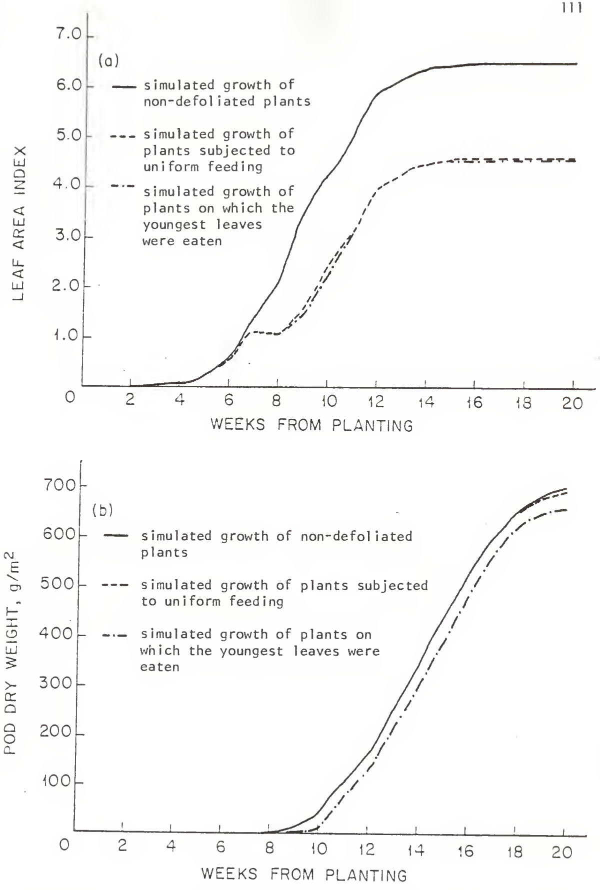


Figure 15. The simulated effect of 10 larvae/plant entering the field on day 35 after planting and feeding for 26 days at an increasing rate.

pod dry weight if the plants were fed upon randomly, but 6% reduction if the feeding was on the youngest leaves (Figure 16). When the population was increased to 20/plant (Figure 17) a much more serious reduction in yield occurred when the insects entered the field at day 35. Final pod dry weight was 27% lower than the check for the plants defoliated randomly and 29% lower for plants on which the youngest leaves were eaten. There was less of a difference in final yield between types of feeding damage in this case because LAI was reduced to almost zero by either type of feeding.

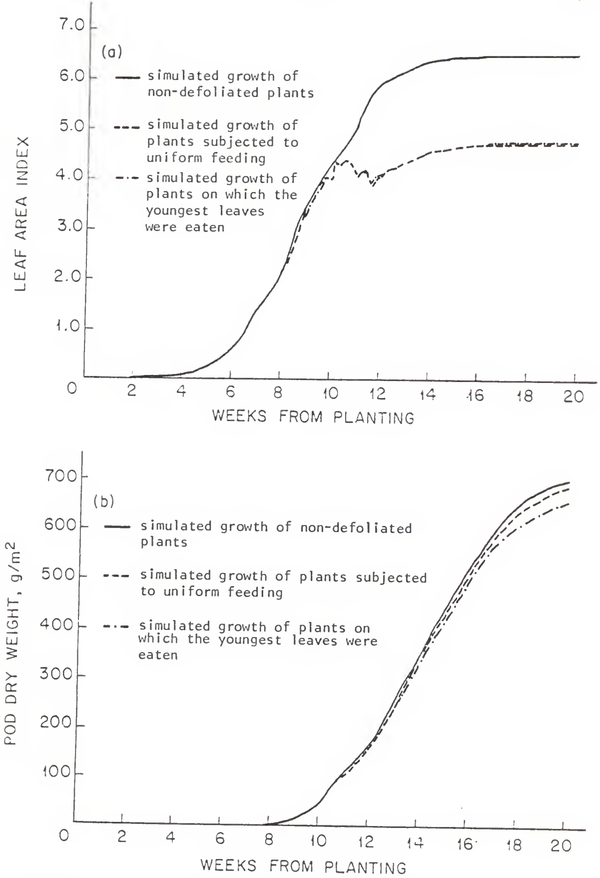
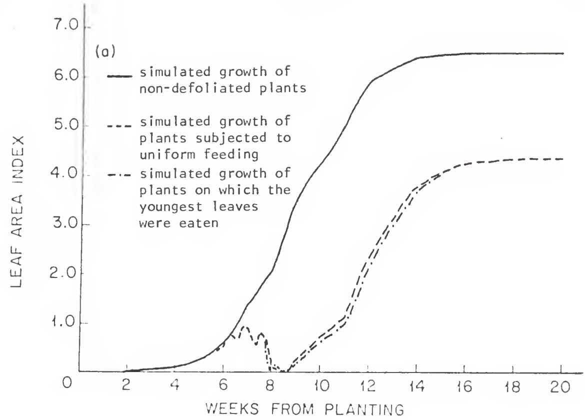


Figure 16. The simulated effect on LAI (a) and pod dry weight (b) of 10 larvae/plant entering the field on day 56 and feeding for 26 days at an increasing rate.



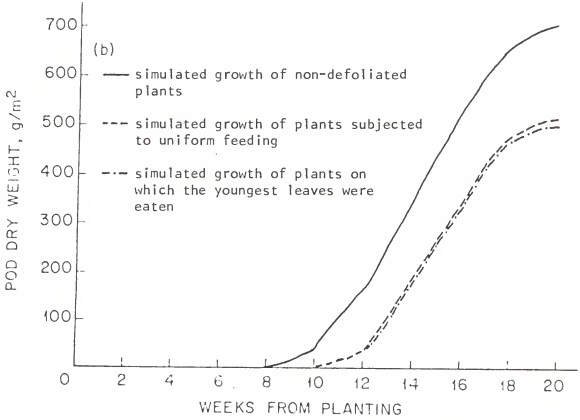


Figure 17. The simulated effect on LAI (a) and pod dry weight (b) of 20 larvae/plant entering the field on day 35 and feeding for 26 days at an increasing rate.

CHAPTER V
SUMMARY AND CONCLUSIONS

The growth of Florunner peanuts was followed on a weekly basis during the summer of 1978. For these plants leaf growth slowed down after week 12 and ceased after week 17. Stem growth, as indicated by the ratio of stem weight to length, continued until week 14, and there was a high correlation between stem weight to length ratio and plant age. The pod load was set by week 12, in that very few pegs that entered the ground after week 12 had expanded into pods by week 16.

A series of defoliation experiments was also performed. For the plants defoliated at $4\frac{1}{2}$ weeks, all plant parts appeared to be equally affected by defoliation; i.e., if stem weight was reduced, so were root weight and leaf number and weight. In the later experiments, stem growth was affected more than leaf growth. Leaf weight for the defoliated plants increased as much as or more than did that for the check plants in the 2 weeks immediately following treatment. Removal of leaves from the outer portion of the canopy resulted in a greater number of new vegetative branches and in more new leaves 2 weeks following treatment. This high level of leaf growth following defoliation was at the expense of stem and pod growth. In all cases the ratio of stem weight to length for defoliated plants was lower than for the control plants. Even at week 16, when stem elongation had ceased, this ratio was negatively affected by defoliation, indicating that the plants

were drawing upon reserves in the stem to grow leaves and pods. Generally, the effect of defoliation upon pod growth appeared to be to slow or stop the expansion of young pods, thereby resulting in fewer pods of the largest size category.

In general, the computer model developed on the basis of these experiments, PMINUS, satisfactorily simulates changes in LAI and weight of stems, pods, and fully expanded pods for both defoliated and control plants. Further work needs to be done on determining factors which cause the plants to lose leaves and to decrease growth of leaves. Further experimentation aimed at determining the mechanisms involved in setting the size of the pod load would also be helpful. It would also be of value to know how long a peg that has entered the ground can remain inactive before it loses the capacity for expansion. A series of defoliation and depodding experiments could shed light on some of these questions. In particular, 100% defoliations and 100% depoddings performed at frequent intervals during the season on 2 or more varieties of peanuts could provide the necessary information on what factors determine the cessation of vegetative growth and the partitioning of photosynthate to pods.

The fact that simulated plant growth following defoliation for the most part matched plant growth in the field indicates that the assumptions made about light interception and photosynthesis in the model are realistic. Further experiments still need to be performed to determine the effect of non-uniform defoliation on canopy photosynthesis. Work also needs to be done on the related problem of feeding site location for different foliage-consuming insects and the effect of natural infestations of insects on canopy photosynthesis. The simulations of an

insect cohort entering the system support the view that time in the season and distribution of feeding damage do influence the plants' ability to tolerate an insect attack.

The model structure is such that the influence of other components of the crop system which affect plant growth and final yield, such as disease and water stress, can be incorporated fairly easily. There is already a water stress subroutine developed by Ritchie (1972) included in PENUTZ. With minor changes it could be incorporated into PMINUS. GASP IV, the simulation language used in construction of this model, allows for the easy programming of events. This makes it possible to simulate insect or disease attacks of some complexity with relative ease.

More research is needed to refine the model for use in a pest management program. At present, it can be a useful research tool in the study of plant response to pest damage. With further comparisons between results of field experiments and model predictions, it should become clearer which of the various hypotheses incorporated in the model are in need of modification.

APPENDIX 1
WEATHER DATA FOR THE 1978 GROWING SEASON

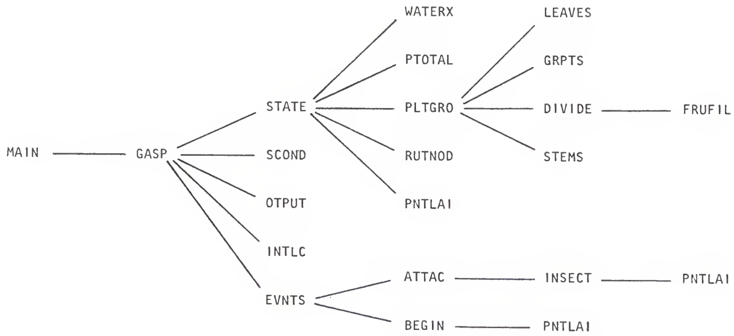
DAY	Solar Radiation, langleys	Temperature (°C) Max.	Temperature (°C) Min.	Rainfall and Irrigation, mm
23 May	449	33.9	21.1	
24 May	545	31.7	21.7	
25 May	487	32.8	20.6	5.1
26 May	593	32.8	20.0	
27 May	614	31.7	16.1	
28 May	566	31.7	18.3	
29 May	533	31.7	18.3	
30 May	550	32.2	20.0	
31 May	397	32.2	19.4	5.8
1 June	550	32.8	20.0	
2 June	392	31.1	22.2	6.3
3 June	292	30.0	21.7	25.9
4 June	277	28.3	22.2	8.8
5 June	368	28.3	21.1	
6 June	485	31.1	22.2	
7 June	540	31.1	23.3	.5
8 June	502	33.3	24.4	
9 June	425	32.2	23.9	2.5
10 June	449	31.7	23.9	14.7
11 June	449	31.7	23.3	.3
12 June	461	31.1	20.6	
13 June	576	32.2	23.3	
14 June	456	31.1	23.3	7.9
15 June	464	28.3	20.0	
16 June	519	30.6	18.9	
17 June	619	30.6	18.9	
18 June	614	30.6	17.8	
19 June	507	30.6	22.2	
20 June	313	29.4	22.2	
21 June	406	32.2	21.1	10.2
22 June	447	30.6	22.2	1.0
23 June	578	32.8	22.2	
24 June	478	34.4	20.6	26.9
25 June	600	32.2	22.8	
26 June	597	33.9	22.2	
27 June	571	33.3	23.9	
28 June	497	35.0	23.9	
29 June	554	35.0	23.9	
30 June	600	35.0	23.9	

Day	Solar Radiation, langleys	Temperature (^{o}C) Max.	Min.	Rainfall and Irrigation, mm
1 July	624	33.9	23.3	
2 July	636	34.4	23.3	
3 July	638	33.9	25.0	
4 July	294	28.3	23.9	3.3
5 July	430	31.1	23.9	6.4
6 July	258	27.8	21.1	5.3
7 July	335	22.8	20.0	8.4
8 July	478	31.1	22.2	1.2
9 July	609	31.1	22.2	3.8
10 July	590	33.3	23.3	
11 July	449	33.3	23.3	
12 July	270	30.6	22.2	9.9
13 July	370	27.8	22.3	.8
14 July	425	30.0	22.8	
15 July	480	31.1	23.3	
16 July	103	31.1	23.3	37.6
17 July	392	30.6	22.8	8.4
18 July	485	30.0	23.3	10.1
19 July	397	30.6	21.7	4.3
20 July	411	28.9	22.2	.3
21 July	519	32.2	22.2	.8
22 July	533	32.2	23.3	6.6
23 July	624	32.2	23.3	
24 July	628	32.2	22.2	.3
25 July	583	33.9	22.8	2.0
26 July	337	30.6	21.7	1.3
27 July	454	31.1	22.8	77.5
28 July	220	27.8	23.3	7.1
29 July	330	29.4	22.8	9.1
30 July	411	31.1	23.9	6.6
31 July	249	30.6	21.1	
1 August	432	30.6	21.1	82.8
2 August	502	31.7	22.2	11.9
3 August	614	31.7	21.1	
4 August	514	31.1	22.2	
5 August	478	30.6	22.8	2.3
6 August	313	31.7	22.2	
7 August	571	33.3	21.7	
8 August	311	30.0	23.9	.3
9 August	633	31.7	21.7	4.6
10 August	387	30.6	22.2	.8
11 August	280	30.0	22.8	12.2
12 August	342	31.7	23.3	2.8
13 August	249	28.9	22.8	1.0
14 August	380	30.0	22.2	
15 August	485	33.3	22.8	50.1

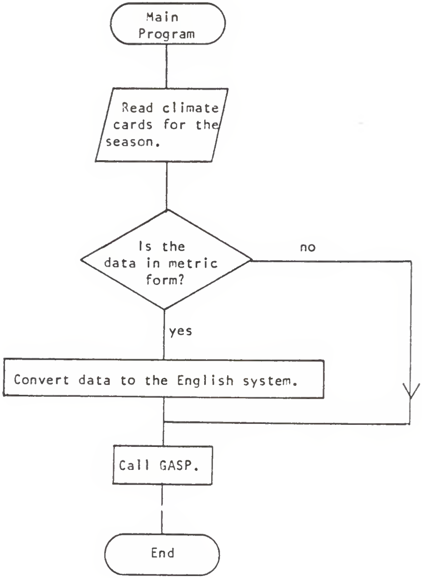
Day	Solar Radiation, langleys	Temperature (°C) Max.	Min.	Rainfall and Irrigation, mm
16 August	387	31.7	22.8	.5
17 August	464	32.8	21.7	2.3
18 August	576	33.9	21.1	2.3
19 August	382	31.7	20.0	
20 August	516	33.3	23.9	
21 August	542	32.2	21.1	
22 August	428	31.7	22.2	
23 August	473	31.1	22.2	
24 August	547	31.7	21.1	
25 August	456	31.7	20.0	12.7
26 August	499	32.2	21.1	
27 August	593	33.9	22.2	
28 August	476	35.0	22.2	
29 August	571	32.2	22.2	
30 August	573	32.8	22.8	
31 August	509	32.8	21.7	19.1
1 September	466	35.0	21.7	
2 September	413	33.3	21.7	1.8
3 September	511	32.8	21.7	
4 September	516	33.3	20.0	
5 September	437	33.9	19.4	
6 September	459	31.1	18.3	
7 September	535	32.2	20.0	
8 September	425	32.8	23.3	19.1
9 September	378	32.8	22.8	
10 September	217	31.7	20.0	.8
11 September	487	31.7	18.9	
12 September	499	32.2	21.7	
13 September	449	32.8	20.0	
14 September	411	32.8	20.6	19.1
15 September	416	33.3	21.1	
16 September	410	33.3	20.6	
17 September	490	32.8	20.0	
18 September	509	32.8	20.6	
19 September	468	33.3	16.1	
20 September	483	32.2	20.6	19.1
21 September	380	32.2	20.9	
22 September	459	33.9	20.6	
23 September	251	32.2	21.1	7.6
24 September	385	31.1	21.7	
25 September	435	31.7	20.6	.8
26 September	354	30.0	20.6	12.7
27 September	292	29.4	20.0	
28 September	378	28.3	18.3	
29 September	170	27.2	20.6	
30 September	129	25.6	22.2	7.9

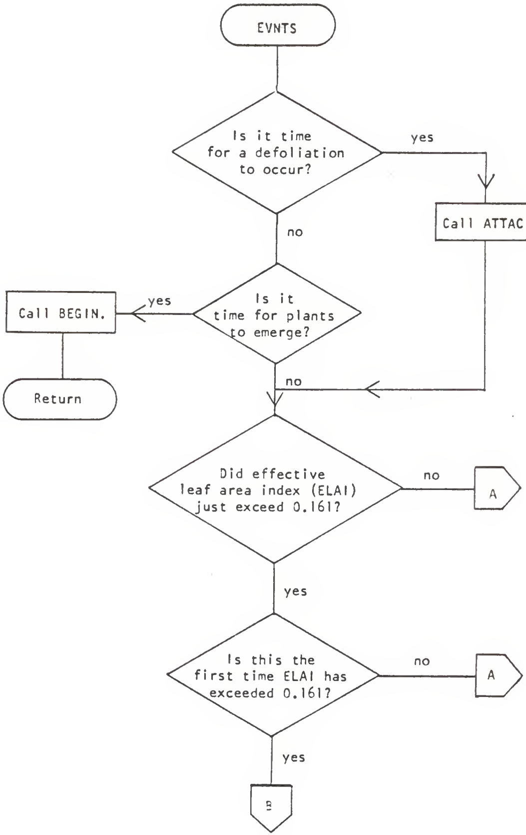
Day	Solar Radiation, langleys	Temperature (°C)		Rainfall and Irrigation, mm
		Max.	Min.	
1 October	306	28.9	17.2	
2 October	456	28.9	16.1	12.7
3 October	485	29.4	19.4	
4 October	308	29.4	15.6	

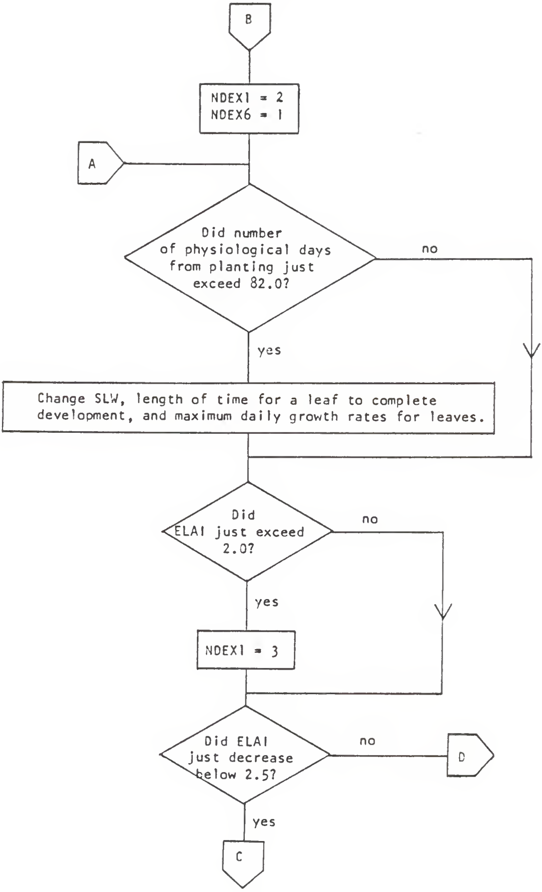
APPENDIX 2
FLOW CHARTS OF THE MAJOR SUBROUTINES IN PMINUS

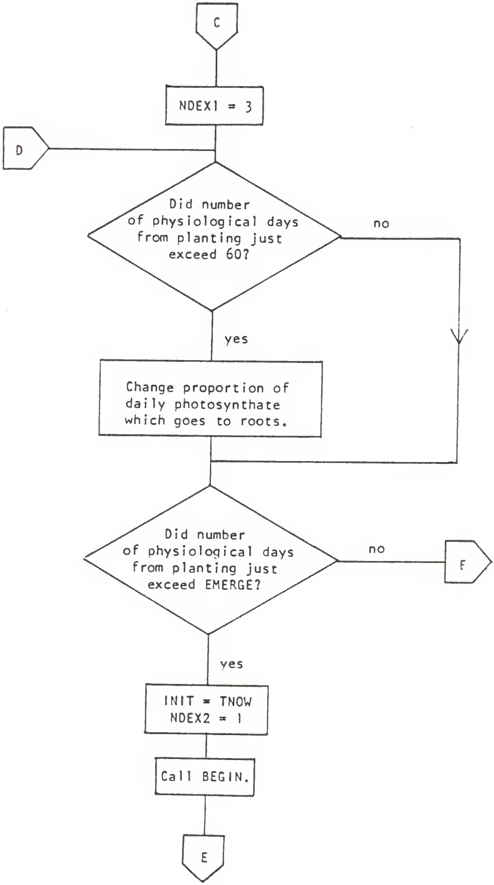


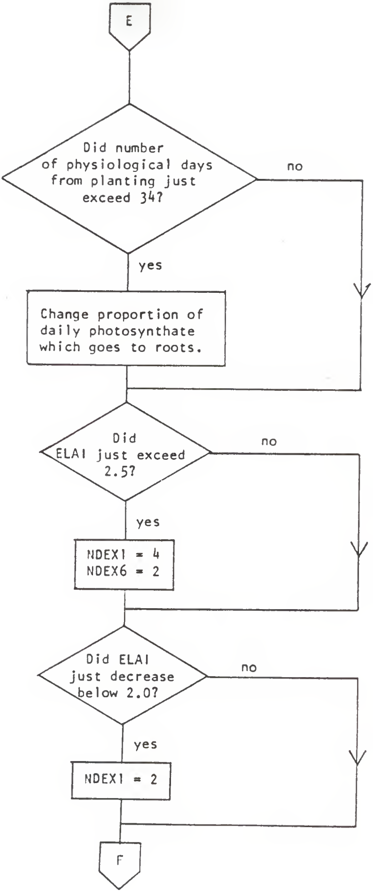
Systems flow diagram showing the relationships between GASP IV (Pritsker 1974) and PMINUS subroutines. (See Table 23 for a functional description of these subroutines.)

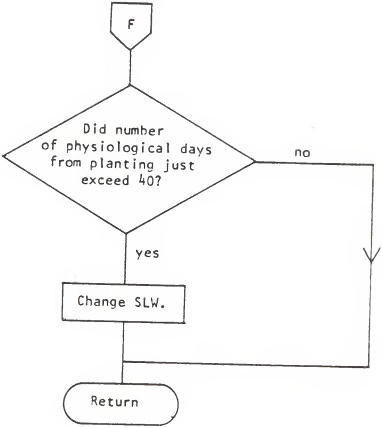

Main
Program
Read climate
cards for the
season.
Is the
data in metric
form?
no
yes
Convert data to the English system.
Call GASP.
End

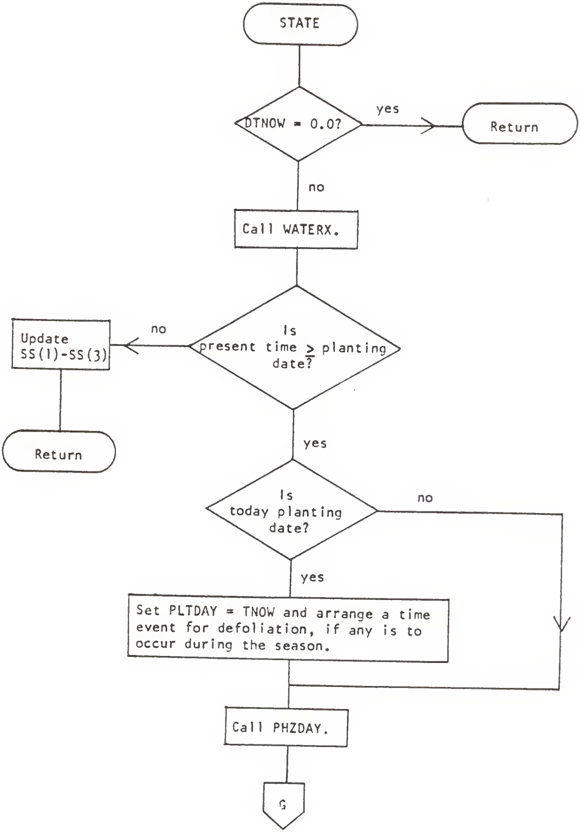

EVNTS
Is it time for a defoliation to occur?
yes
Call ATTAC.
no
Is it time for plants to emerge?
yes
Call BEGIN.
Return
no
Did effective leaf area index (ELAI) just exceed 0.161?
no
A
yes
Is this the first time ELAI has exceeded 0.161?
no
A
yes
B

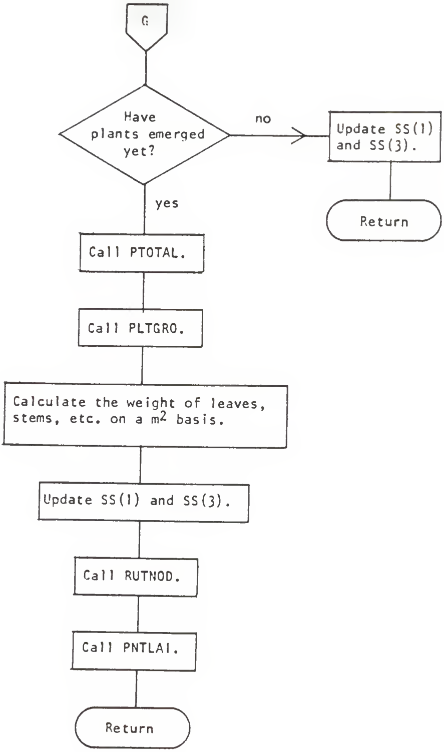

B
NDEX1 = 2
NDEX6 = 1
A
Did number of physiological days from planting just exceed 82.0?
no
yes
Change SLW, length of time for a leaf to complete development, and maximum daily growth rates for leaves.
Did ELAI just exceed 2.0?
no
yes
NDEX1 = 3
Did ELAI just decrease below 2.5?
no
D
yes
C

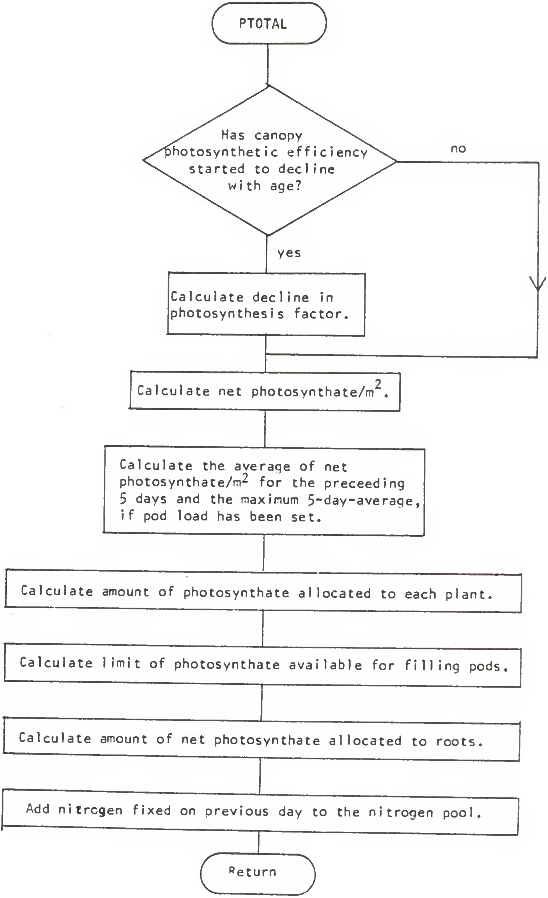

C
NDEX1 = 3
D
Did number of physiological days from planting just exceed 60?
no
yes
Change proportion of daily photosynthate which goes to roots.
Did number of physiological days from planting just exceed EMERGE?
no
F
yes
INIT = TNOW
NDEX2 = 1
Call BEGIN.
E

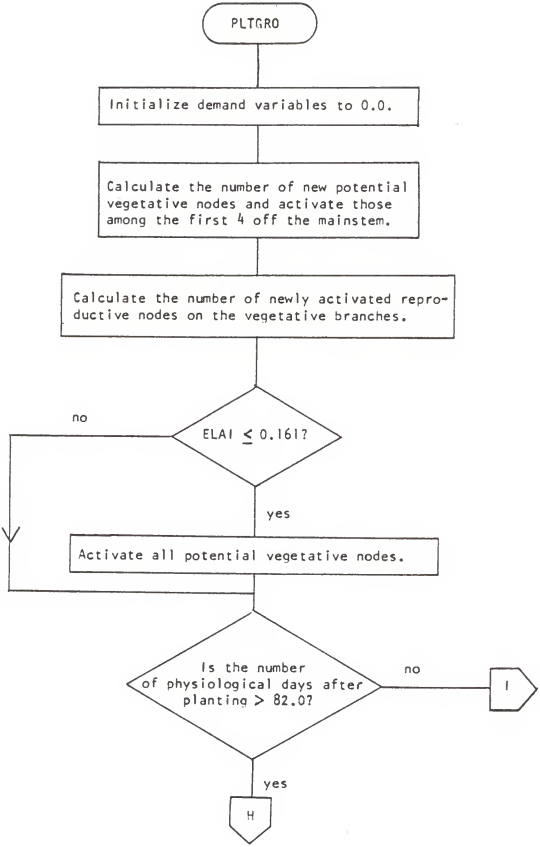

E
Did number of physiological days from planting just exceed 34?
no
yes
Change proportion of daily photosynthate which goes to roots.
Did ELAI just exceed 2.5?
no
yes
NDEX1 = 4
NDEX6 = 2
Did ELAI just decrease below 2.0?
no
yes
NDEX1 = 2
F

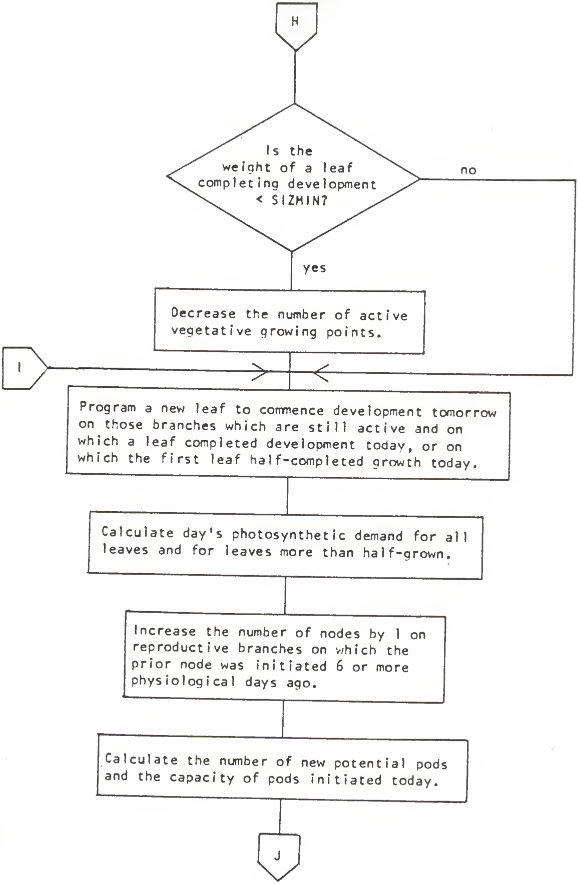

F
Did number of physiological days from planting just exceed 40?
no
yes
Change SLW.
Return

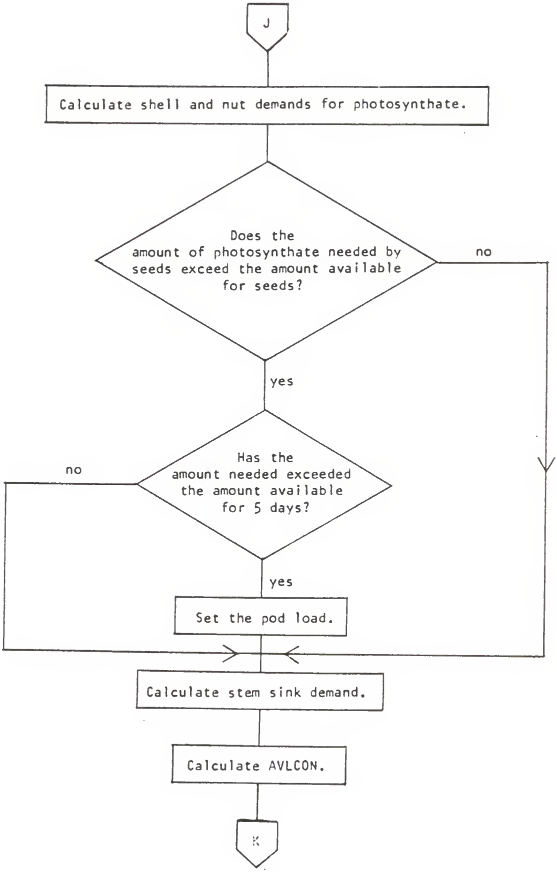

STATE
DTNOW = 0.0?
yes
Return
no
Call WATERX.
Is present time ≥ planting date?
no
Update SS(1)-SS(3)
Return
yes
Is today planting date?
no
yes
Set PLTDAY = TNOW and arrange a time event for defoliation, if any is to occur during the season.
Call PHZDAY.
G

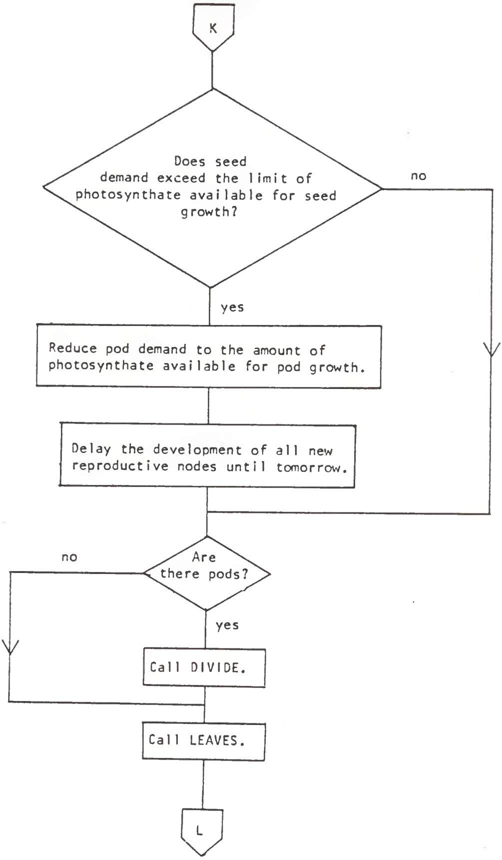

G
Have plants emerged yet?
no
Update SS(1) and SS(3).
Return
yes
Call PTOTAL.
Call PLTGRO.
Calculate the weight of leaves, stems, etc. on a m2 basis.
Update SS(1) and SS(3).
Call RUTNOD.
Call PNTLAI.
Return

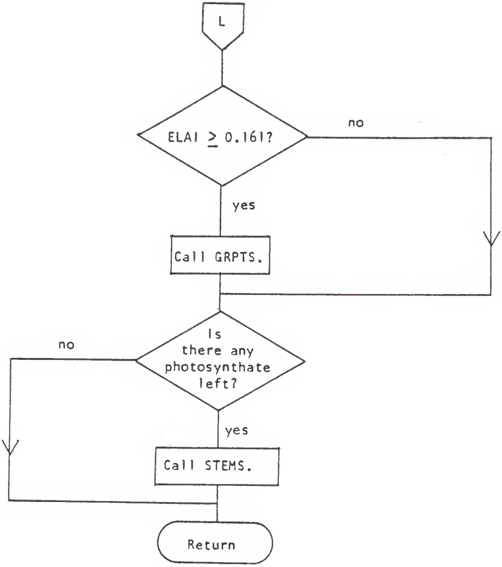

PTOTAL
Has canopy photosynthetic efficiency started to decline with age?
no
yes
Calculate decline in photosynthesis factor.
Calculate net photosynthate/m².
Calculate the average of net photosynthate/m² for the preceeding 5 days and the maximum 5-day-average, if pod load has been set.
Calculate amount of photosynthate allocated to each plant.
Calculate limit of photosynthate available for filling pods.
Calculate amount of net photosynthate allocated to roots.
Add nitrogen fixed on previous day to the nitrogen pool.
Return


PLTGRO
Initialize demand variables to 0.0.
Calculate the number of new potential vegetative nodes and activate those among the first 4 off the mainstem.
Calculate the number of newly activated reproductive nodes on the vegetative branches.
ELAI ≤ 0.161?
no
yes
Activate all potential vegetative nodes.
Is the number of physiological days after planting > 82.0?
no
I
yes
H

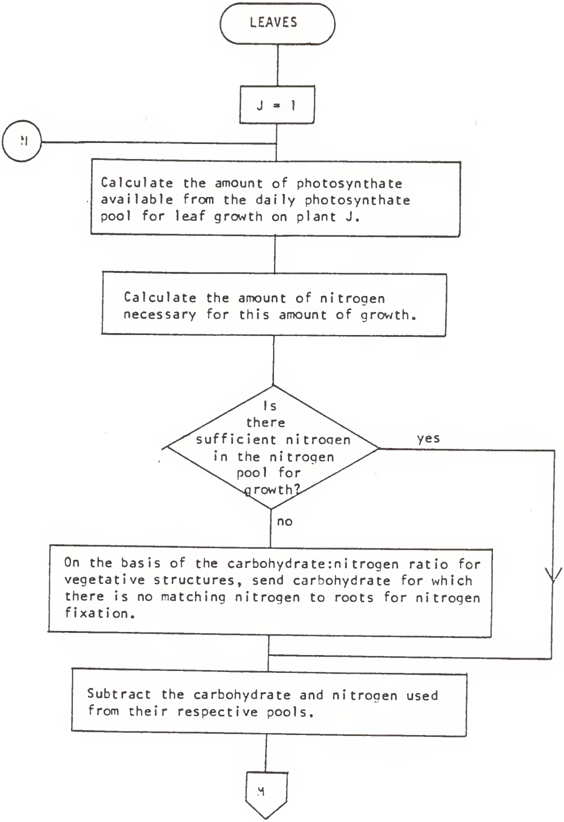

H
Is the weight of a leaf completing development < SIZMIN?
no
yes
Decrease the number of active vegetative growing points.
I
Program a new leaf to commence development tomorrow on those branches which are still active and on which a leaf completed development today, or on which the first leaf half-completed growth today.
Calculate day's photosynthetic demand for all leaves and for leaves more than half-grown.
Increase the number of nodes by 1 on reproductive branches on which the prior node was initiated 6 or more physiological days ago.
Calculate the number of new potential pods and the capacity of pods initiated today.
J

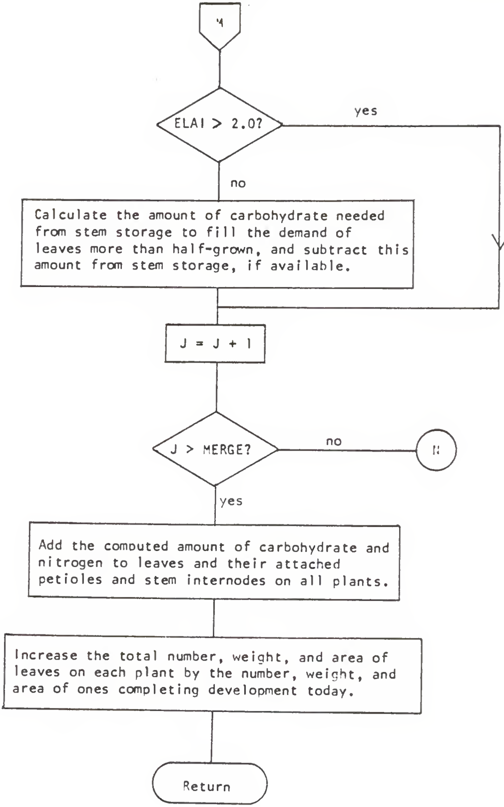

J
Calculate shell and nut demands for photosynthate.
Does the amount of photosynthate needed by seeds exceed the amount available for seeds?
no
yes
Has the amount needed exceeded the amount available for 5 days?
no
yes
Set the pod load.
Calculate stem sink demand.
Calculate AVLCON.
K

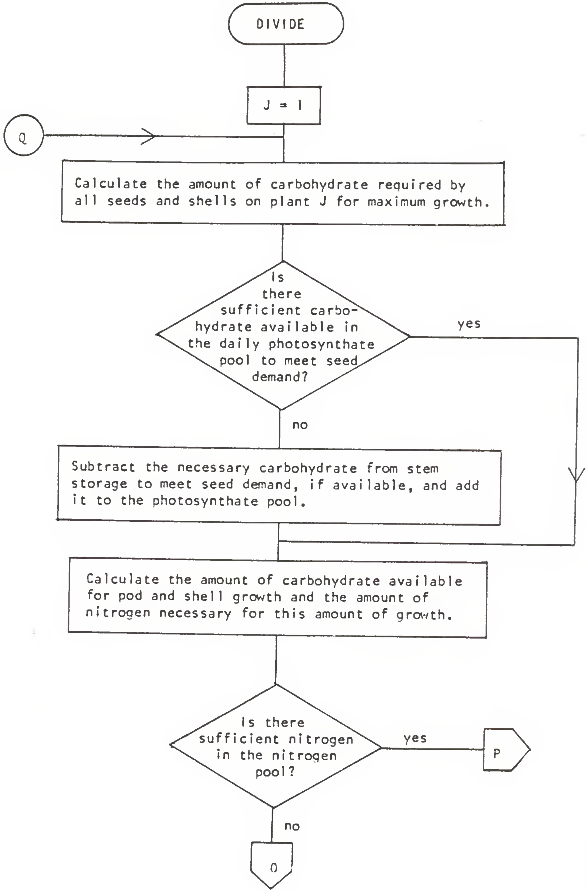

K
Does seed demand exceed the limit of photosynthate available for seed growth?
no
yes
Reduce pod demand to the amount of photosynthate available for pod growth.
Delay the development of all new reproductive nodes until tomorrow.
Are there pods?
no
yes
Call DIVIDE.
Call LEAVES.
L

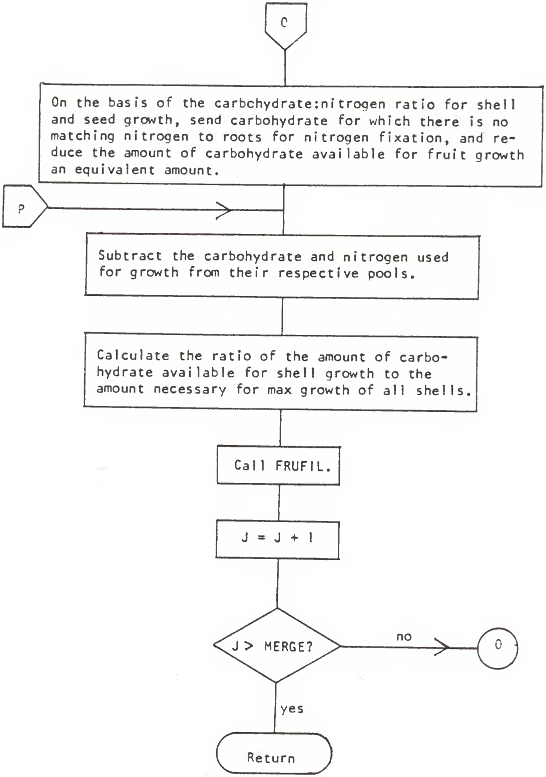


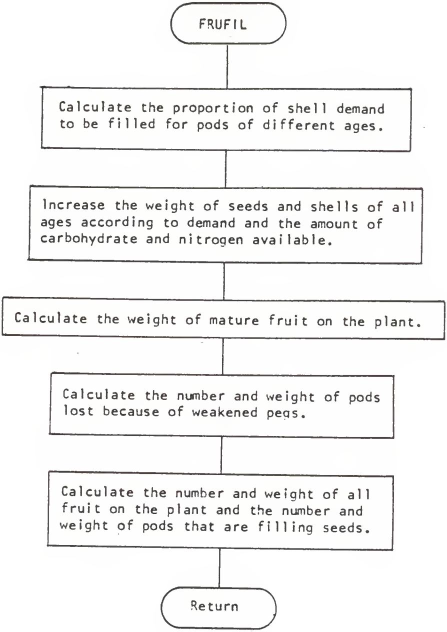
L
ELAI $\geq$ 0.161?
no
yes
Call GRPTS.
Is there any photosynthate left?
no
yes
Call STEMS.
Return

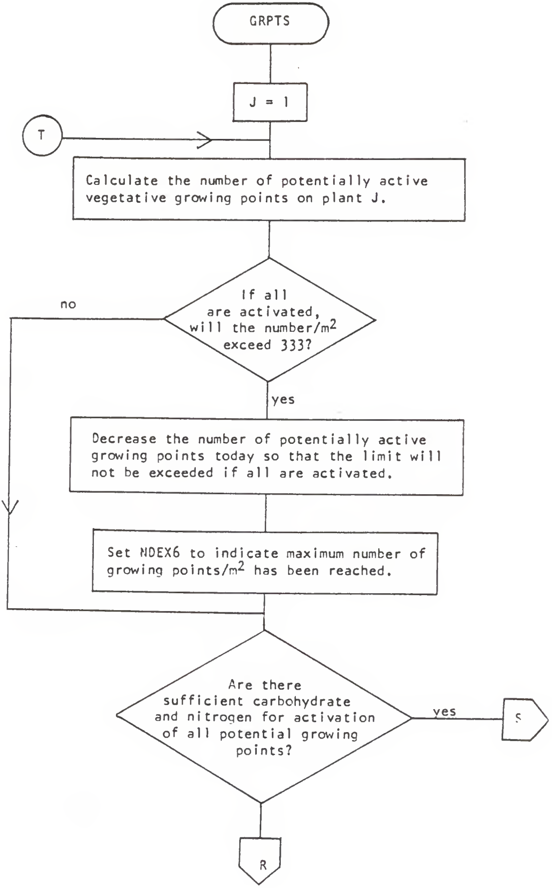

LEAVES
J = 1
M
Calculate the amount of photosynthate available from the daily photosynthate pool for leaf growth on plant J.
Calculate the amount of nitrogen necessary for this amount of growth.
Is there sufficient nitrogen in the nitrogen pool for growth?
yes
no
On the basis of the carbohydrate:nitrogen ratio for vegetative structures, send carbohydrate for which there is no matching nitrogen to roots for nitrogen fixation.
Subtract the carbohydrate and nitrogen used from their respective pools.
M

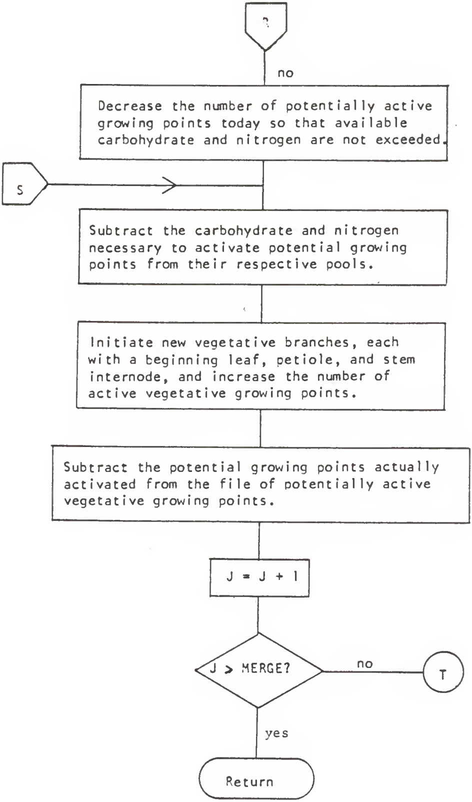

ELAI > 2.0?
yes
no
Calculate the amount of carbohydrate needed from stem storage to fill the demand of leaves more than half-grown, and subtract this amount from stem storage, if available.
J = J + 1
J > MERGE?
no
yes
Add the computed amount of carbohydrate and nitrogen to leaves and their attached petioles and stem internodes on all plants.
Increase the total number, weight, and area of leaves on each plant by the number, weight, and area of ones completing development today.
Return

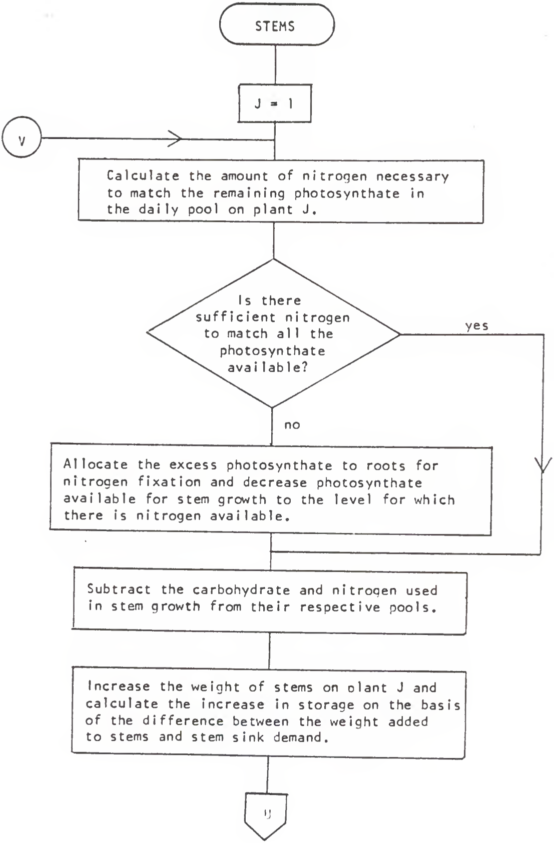

DIVIDE
J = 1
Q
Calculate the amount of carbohydrate required by all seeds and shells on plant J for maximum growth.
Is there sufficient carbohydrate available in the daily photosynthate pool to meet seed demand?
yes
no
Subtract the necessary carbohydrate from stem storage to meet seed demand, if available, and add it to the photosynthate pool.
Calculate the amount of carbohydrate available for pod and shell growth and the amount of nitrogen necessary for this amount of growth.
Is there sufficient nitrogen in the nitrogen pool?
yes
P
no
O

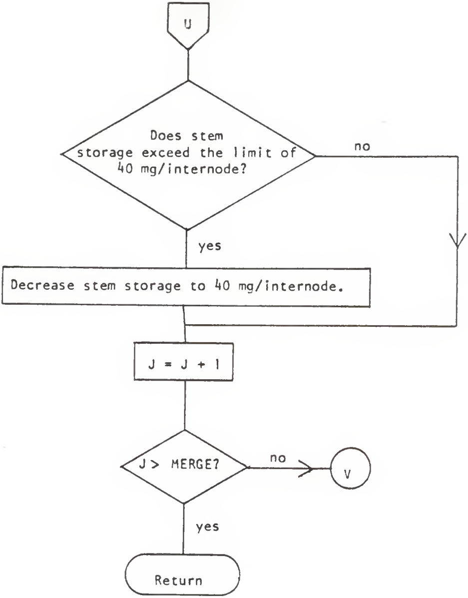

C
On the basis of the carbchydrate:nitrogen ratio for shell and seed growth, send carbohydrate for which there is no matching nitrogen to roots for nitrogen fixation, and reduce the amount of carbohydrate available for fruit growth an equivalent amount.
P
Subtract the carbohydrate and nitrogen used for growth from their respective pools.
Calculate the ratio of the amount of carbohydrate available for shell growth to the amount necessary for max growth of all shells.
Call FRUFIL.
J = J + 1
J > MERGE?
no
O
yes
Return

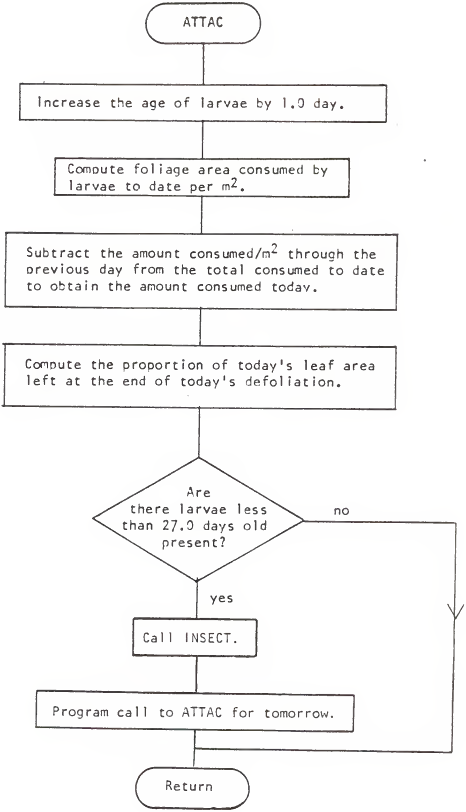

FRUFIL
Calculate the proportion of shell demand to be filled for pods of different ages.
Increase the weight of seeds and shells of all ages according to demand and the amount of carbohydrate and nitrogen available.
Calculate the weight of mature fruit on the plant.
Calculate the number and weight of pods lost because of weakened pegs.
Calculate the number and weight of all fruit on the plant and the number and weight of pods that are filling seeds.
Return


GRPTS
J = 1
T
Calculate the number of potentially active vegetative growing points on plant J.
If all are activated, will the number/m2 exceed 333?
no
yes
Decrease the number of potentially active growing points today so that the limit will not be exceeded if all are activated.
Set NDEX6 to indicate maximum number of growing points/m2 has been reached.
Are there sufficient carbohydrate and nitrogen for activation of all potential growing points?
yes
S
R


no
Decrease the number of potentially active growing points today so that available carbohydrate and nitrogen are not exceeded.
S
Subtract the carbohydrate and nitrogen necessary to activate potential growing points from their respective pools.
Initiate new vegetative branches, each with a beginning leaf, petiole, and stem internode, and increase the number of active vegetative growing points.
Subtract the potential growing points actually activated from the file of potentially active vegetative growing points.
J = J + 1
J > MERGE?
no
T
yes
Return


STEMS
J = 1
V
Calculate the amount of nitrogen necessary to match the remaining photosynthate in the daily pool on plant J.
Is there sufficient nitrogen to match all the photosynthate available?
yes
no
Allocate the excess photosynthate to roots for nitrogen fixation and decrease photosynthate available for stem growth to the level for which there is nitrogen available.
Subtract the carbohydrate and nitrogen used in stem growth from their respective pools.
Increase the weight of stems on plant J and calculate the increase in storage on the basis of the difference between the weight added to stems and stem sink demand.


U
Does stem storage exceed the limit of 40 mg/internode?
no
yes
Decrease stem storage to 40 mg/internode.
J = J + 1
J > MERGE?
no
V
yes
Return


ATTAC
Increase the age of larvae by 1.0 day.
Compute foliage area consumed by larvae to date per m2.
Subtract the amount consumed/m2 through the previous day from the total consumed to date to obtain the amount consumed today.
Compute the proportion of today's leaf area left at the end of today's defoliation.
Are there larvae less than 27.0 days old present?
no
yes
Call INSECT.
Program call to ATTAC for tomorrow.
Return

INSECT

Calculate PLTMAX--maximum of 0.60 * PLTLAI and the previous values for PLTMAX.

Calculate percent defoliation today.

Calculate the weight and area of leaves left on the plant, depending on the type and level of defoliation.

Calculate new leaf area index, SS(3).

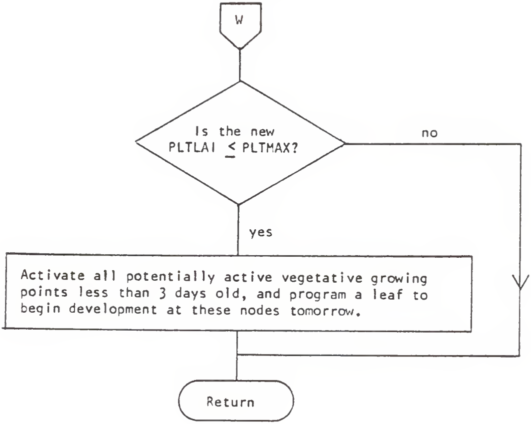
Calculate the destruction of vegetative meristems, if any.

Program the initiation of new vegetative branches at the last 2 nodes on any branches on which the apical meristem has been destroyed, if the nodes are vegetative.

Calculate ELAI, SS(1).

Call PNTLAI.

V


W
Is the new
PLTLAI ≤ PLTMAX?
no
yes
Activate all potentially active vegetative growing points less than 3 days old, and program a leaf to begin development at these nodes tomorrow.
Return

APPENDIX 3
COMPUTER PRINTOUT OF PMINUS

```
      DIMENSION NSET(500)
      COMMON QSET(500)
      COMMON /GCOM1/ ATRIB(25),JEVNT,MFA,MFE(100),MLE(100),MSTOP,NCRDR,N
     1NAPO,NNAPT,NNATR,NNFIL,NNQ(100),NNTRY,NPRNT,PPARM(50,4),TNOW,TTBEG
     2,TTCLR,TTFIN,TTRIB(25),TTSET
      COMMON /GCOM2/ DD(100),DDL(100),DTFUL,DTNOW,ISEES,LFLAG(50),NFLAG,
     1NNEQD,NNEQS,NNEQT,SS(100),SSL(100),TTNEX
      COMMON /GCOM3/ AAERR,DTMAX,DTMIN,DTSAV,IITES,LLERR,LLSAV,LLSEV,RRE
     1PR,TTLAS,TTSAV
      COMMON /GCOM4/ DTPLT(10),HHLOW(25),HHWID(25),IICRD,IITAP(10),JJCEL
     1(500),LLABC(25,2),LLABH(25,2),LLABP(11,2),LLABT(25,2),LLPHI(10),LL
     2PLD(10),LLPLT,LLSUP(15),LLSYM(10),MMPTS,NNCFL(25),NNCLT,NNHIS,NNPL
     3T,NNPTS(10),NNSTA,NNVAR(10),PPHI(10),PPLG(10)
      COMMON /GCOM5/ IIEVT,IISED(6),JJBEG,JJCLR,MMNIT,MMON,NNAME(3),NNCF
     1I,NNDAY,NNPT,NNSET,NNPRJ,NNPRM,NNRUNS,NNRUN,NNSTR,NNYR,SSEED(6)
      COMMON /GCOM6/ EENQ(100),IINN(100),KKRNK(100),MMAXQ(100),QQTIM(100
     1),SSOBV(25,5),SSTPV(25,6),VVNQ(100)
      COMMON /UCOM5/CLIMAT(200,6)
      COMMON /UCOM28/TTL(20)
      EQUIVALENCE (NSET(1),QSET(1))
      NCRDR=5
      NPRNT=6
      READ (5,1000) TTL
      READ (5,1001) TMETRC
      DO 10 J = 1,200
      READ (5,1002)(CLIMAT(J,K),K=1,6)
      L = CLIMAT(J,1)
      IF (L + 1) 20,20,10
   10 CONTINUE
   20 IF (TMETRC.NE.1.0) GO TO 40
      DO 30 I = 1,J
      CLIMAT(I,2) = CLIMAT(I,2) * 1.8 + 32.0
      CLIMAT(I,3) = CLIMAT(I,3) * 1.8 + 32.0
      CLIMAT(I,4) = CLIMAT(I,4) * 0.03937
   30 CLIMAT(I,5) = CLIMAT(I,5) * 0.03937
   40 DO 50 I = J,200
      CLIMAT(I,1) = CLIMAT(J-1,1)
      CLIMAT(I,2) = CLIMAT(J-1,2)
      CLIMAT(I,3) = CLIMAT(J-1,3)
      CLIMAT(I,4) = CLIMAT(J-1,4)
      CLIMAT(I,5) = CLIMAT(J-1,5)
      CLIMAT(I,6) = 0.0
   50 CONTINUE
      CALL GASP
 1000 FORMAT (20A4)
 1001 FORMAT (F10.0)
 1002 FORMAT (6F10.0)
      STOP
```

```
      SUBROUTINE INTLC
      COMMON /GCOM1/ ATRIB(25),JEVNT,MFA,MFE(100),MLE(100),MSTOP,NCRDR,N
     1NAPO,NNAPT,NNATR,NNFIL,NNQ(100),NNTRY,NPRNT,PPARM(50,4),TNOW,TTBEG
     2,TTCLR,TTFIN,TTRIB(25),TTSET
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1          ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM4/ADDSTM
      COMMON /UCOM8/PROPOR(7),DAYADD
      COMMON /UCOM16/PORT(7)
      COMMON /UCOM22/NEWVEG(7,200),ADDLF
      COMMON / UCOM24/XNODOD(7),NCOUNT(200),SURFAC(7,200),VEGGRO,
     2          VEGNIT,VEGNCR,ASVEGF,VEGCNR,PORLF,PORPT,PORNOD,SLW
      COMMON /UCOM27/PCTC,PODC,PCTN,PODN,ASPPRO,OILFAC
      COMMON /UCOM36/PLTPOP
      DATA VEGPRO,PNTPRO,PNTOIL/ 12.0,23.0,50.0/
      DATA ROWSPC,ROWMID/ 13.81,76.20/
      VEGNCR = VEGPRO / (97.0 - VEGPRO)
      VEGCNR = (97.0 - VEGPRO) / VEGPRO
      ADDLF = (14.09 * 0.97) / (1.0 + VEGNCR)
      PORLF = 8.21 * 0.97
      PORPT = 2.88 * 0.97
      PORNOD = 3.0 * 0.97
      SLW = 4.98
      PNTNCR = PNTPRO / (95.0 - PNTPRO)
      PCTC = 0.95 / (1.0 + PNTNCR)
      PODC = 0.97 / (1.0 + VEGNCR)
      PNTCNR = (95.0 - PNTPRO) / PNTPRO
      PCTN = 0.95 / (1.0 + PNTCNR)
      PODN = 0.97 / (1.0 + VEGCNR)
      ASVEGF = 4.714/ 6.0
      ASPPRO = 4.714 / 5.46
      OILFAC = (95.0 - PNTPRO) / ((PNTOIL * 2.85) + (95.0 - PNTOIL -
     1          PNTPRO))
      ADDSTM = (3.0 * 0.97) / (1.0 + VEGNCR)
      PLTPOP = 1.0E4 / (ROWSPC * ROWMID)
      DO 10 J = 1,MERGE
   10 PROPOR(J) = PORT(J) * PLTPOP
      RETURN
      END
```

```
      SUBROUTINE EVNTS(IX)
      COMMON /GCOM1/ ATRIB(25),JEVNT,MFA,MFE(100),MLE(100),MSTOP,NCRDR,N
     1NAPO,NNAPT,NNATR,NNFIL,NNQ(100),NNTRY,NPRNT,PPARM(50,4),TNOW,TTBEG
     2,TTCLR,TTFIN,TTRIB(25),TTSET
      COMMON /GCOM2/ DD(100),DDL(100),DTFUL,DTNOW,ISEES,LFLAG(50),NFLAG,
     1NNEQD,NNEQS,NNEQT,SS(100),SSL(100),TTNEX
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1        ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM2/HFTIME,TIMELF
      COMMON /UCOM3/INIT
      COMMON /UCOM4/ADDSTM
      COMMON /UCOM5/ISTEM(7,350),NODE(7,350),XLEAFN(7),SIZELF(7,200),
     1          WTLEAF(7,200),WTINOD(7,200),WIPET(7,200),AREALF(7),
     2          WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROOT(7),ICOUNT(7,350),
     3          PDAY(200),AGRPTS(7)
      COMMON /UCOM21/PODWGT(7,200),MORE,BLOOMZ(7,200),KPEGST,
     1          PEGNO(7,200),PODST(7),PODCAP(7,200),AGEMAX(7,200),GRATEK,
     2          KPODST,GRRATE,PQPODS(7),PQNUTS(7),PODAGE(200)
      COMMON /UCOM22/NEWVEG(7,200),ADDLF
      COMMON / UCOM24/XNONOD(7),NCOUNT(200),SURFAC(7,200),VEGGRO,
     2          VEGNIT,VEGNCR,ASVEGF,VEGCNR,PORLF,PORPT,PORNOD,SLW
      COMMON /UCOM31/ROOTF,SMAINF
      COMMON /UCOM35/NDEX6
      COMMON /UCOM37/NDEX7
      GO TO (1,2,3),IX
    1 CALL ATTAC
      GO TO 3
    2 CALL BEGIN
      GO TO 900
    3 IF (LFLAG(1)) 100,100,10
   10 CONTINUE
      IF (NDEX5.EQ.1) GO TO 100
      NDEX1 = 2
      NDEX5 = 1
      NDEX6 = 1
  100 IF (LFLAG(2)) 200,200,110
  110 SLW = 3.28
      SMAINF = 0.13
      ADDLF = (10.57 * 0.97) / (1.0 + VEGNCR)
      PORLF = 6.16 * 0.97
      PORPT = 2.16 * 0.97
      PORNOD = 2.25 * 0.97
      XX = TIMELF
      HFTIME = 7.2
      TIMELF = 14.4
      DO 220 I = 1,NOW
      IF (PDAY(I).LE.0.0) GO TO 220
      PDAY(I) = TIMELF - (TIMELF/XX) * (XX - PDAY(I))
```

```
220 CONTINUE
    NDEX9 = 1
200 IF (LFLAG(8)) 300,300,210
210 NDEX1 = 3
300 IF (LFLAG(4)) 310,400,400
310 NDEX1 = 3
400 IF (LFLAG(5)) 500,500,410
410 ROOTF = 0.01
    SMAINF = 0.15
500 IF (LFLAG(6)) 600,600,510
510 INIT = TNOW
    NDEX2 = 1
    CALL BEGIN
600 IF (LFLAG(7)) 700,700,610
610 ROOTF = 0.43
    SMAINF = 0.30
700 IF (LFLAG(3)) 800,800,710
710 NDEX1 = 4
    NDEX6 = 2
800 IF (LFLAG(9)) 810,900,900
810 NDEX1 = 2
900 CONTINUE
    IF (LFLAG(10)) 950,950,910
910 SLW = 3.77
950 CONTINUE
    RETURN
    END
```

```
      SUBROUTINE SCOND
      COMMON /GCO42/ DD(100),DDL(100),DTFUL,DTNOW,ISEES,LFLAG(50),NFLAG,
     1NNEQD,NNEQS,NNEQT,SS(100),SSL(100),TTNEX
      DATA EMERGE/11.0/
      LFLAG(1) = KROSS(1,0,0.0,0.161,1,0.2)
      LFLAG(2) = KROSS(2,0,0.0,32.0,1,2.0)
      LFLAG(3) = KROSS(1,0,0.0,2.5,1,2.0)
      LFLAG(4) = KROSS(1,0,0.0,2.5,-1,2.5)
      LFLAG(5) = KROSS(2,0,0.0,60.0,1,2.0)
      LFLAG(6) = KROSS(2,0,0.0,EMERGE,1,2.0)
      LFLAG(7) = KROSS(2,0,0.0,34.0,1,2.0)
      LFLAG(8) = KROSS(1,0,0.0,2.0,1,2.0)
      LFLAG(9) = KROSS(1,0,0.0,2.0,-1,2.0)
      LFLAG(10) = KROSS(2,0,0.0,40.0,1,2.0)
      RETURN
      END
```

```
      SUBROUTINE BEGIN
      COMMON /GCOM1/ ATRIB(25),JEVNT,MFA,MFE(100),MLE(100),MSTOP,NCRDR,N
     1NAPO,NNAPT,NNATR,NNFIL,NNQ(100),NNTRY,NPRNT,PPARM(50,4),TNOW,TTBEG
     2,TTCLR,TTFIN,TTRIB(25),TTSET
      COMMON /GCOM2/ DD(100),DDL(100),DTFUL,DTNOW,ISEES,LFLAG(50),NFLAG,
     1NNEQD,NNEQS,NNEQT,SS(100),SSL(100),TTNEX
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1     ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM2/HFTIME,TIMFLF
      COMMON /UCOM3/INIT
      COMMON /UCOM5/ISTEM(7,350),NODE(7,350),XLEAFN(7),SIZELF(7,200),
     1        WTLEAF(7,200),WTINOD(7,200),WTPET(7,200),AREALF(7),
     2        WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROOT(7),ICOUNT(7,350),
     3       PDAY(200),AGRPTS(7)
      COMMON /UCOM8/PROPOR(7),DAYADD
      COMMON /UCOM9/PENUTZ(7),FRUIT(7),HSTPOD(7),HSTFRT(7),PEGS(7),
     1       R(7),PNRIPE(7),PETWT(7)
      COMMON /UCOM14/IMERGE(7)
      COMMON /UCOM20/WANTLF(7),NUMBR(7),XINODE(7,200)
      COMMON / UCOM24/XNONOD(7),NCOUNT(200),SURFAC(7,200),VEGGRO,
     2       VEGNIT,VEGNCR,ASVEGF,VEGCNR,PORLF,PORPT,PORNOD,SLW
      COMMON /UCOM29/LCOUNT(7,350)
      DATA AREANW,WTNEW,STEMNW,PETNEW,ROOTNW/4.37,20.37,8.73,7.13,
     1     21.46/
      NOW = TNOW
      IF (NOW - INIT.GE.MERGL) GO TO 900
      ATRIB(1) = TNOW + 1.
      ATRIB(2) = 2.
      CALL FILEM(1)
      L = TNOW - HFTIME + 1.0
      N = TNOW - HFTIME + 2.4
      K = NOW - INIT + 1
      M = K + 1
      J = 1
      IMERGE(K) = NOW
      ISTEM(K,1) = 1
      ISTEM(K,2) = 2
      ISTEM(K,3) = 2
      NUMBR(K) = 3
      NODE(K,1) = 1
      NODE(K,2) = 2
      NODE(K,3) = 2
      XLEAFN(K) = 1.
      XNONOD(K) = 1.
      SIZELF(K,J) = WTNEW
      WTLEAF(K,J) = WTNEW
      WTINOD(K,J) = STEMNW
      WTPET(K,J) = PETNEW
```

```
      SURFAC(K,J)  = AREANW
      AREALF(K) =  AREANW
      WGHTLF(K) =  WTNEW / (1000. * 0.97)
      WTSTEM(K)  =  STEMNW / (1000. * 0.97)
      PETWT(K) = PETNEW / (1000. * 0.97)
      WTROOT(K) =  ROOTNW / 1000.
      XNLEAF(K,J) = 1.0
      XINODE(K,J) = 1.0
      XX = (TIMELF - 2.0) / TIMELF
      SIZELF(K,M) = WTNEW * XX
      WTLEAF(K,M) = WTNEW * XX
      WTINOD(K,M) = STEMNW * XX
      WTPET(K,M) = PETNEW * XX
      XNLEAF(K,M) = 1.0
      XINODE(K,M) = 1.0
      IF (PDAY(M).LT.TIMELF - 3.0) PDAY(M) = TIMELF - 3.0
      XNLEAF(K,L) = 3.0
      XINODE(K,L) = 3.0
      SIZELF(K,L) = (WTNEW / 2.) * XNLEAF(K,L)
      WTLEAF(K,L) = WTNEW / 2.
      WTINOD(K,L) = STEMNW / 2.
      WTPET(K,L) = (PETNEW / 2.) * XNLEAF(K,L)
      IF (PDAY(L).LT.HFTIME) PDAY(L) = HFTIME
      XX = (HFTIME - 2.0) / TIMELF
      XNLEAF(K,N) = 3.0
      XINODE(K,N) = 3.0
      WTPET(K,N) = PETNEW * XX
      SIZELF(K,N) = 3.0 * WTNEW * XX
      WTLEAF(K,N) = WTNEW * XX
      WTINOD(K,N) = STEMNW * XX
      IF (PDAY(N).LT.HFTIME-2.0) PDAY(N) = HFTIME - 2.0
      ICOUNT(K,1) = N
      ICOUNT(K,2) = N
      ICOUNT(K,3) = N
      NCOUNT(J) = NOW
      AGRPTS(K) = 3.
      SS(1) = SS(1) + (AREALF(K) * PROPOR(K)) / 10000.
      SS(3) = SS(3) + (AREALF(K) * PROPOR(K)) / 10000.
      CALL PNTLAI
  900 RETURN
      END
```

```
      SUBROUTINE STATE
      COMMON /GCOM1/ ATRIB(25),JEVNT,MFA,MFE(100),MLE(100),MSTOP,NCRDR,N
     1NAPO,NNAPT,NNATR,NNFIL,NNQ(100),NNTRY,NPRNT,PPARM(50,4),TNOW,TTBEG
     2,TTCLR,TTFIN,TTRIB(25),TTSET
      COMMON /GCOM2/ DD(100),DDL(100),DTFUL,DTNOW,ISEES,LFLAG(50),NFLAG,
     1NNEQD,NNEQS,NNEQT,SS(100),SSL(100),TTNEX
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1         ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM5/ISTEM(7,350),NODE(7,350),XLEAFN(7),SIZELF(7,200),
     1           WTLEAF(7,200),WTINOD(7,200),WTPET(7,200),AREALF(7),
     2           WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROOT(7),ICOUNT(7,350),
     3          PDAY(200),AGRPTS(7)
      COMMON /UCOM6/CLIMAT(200,6)
      COMMON /UCOM7/STM42(200),WTLFM2(200),GRPTSM(200),XNOLFM(200),
     1          TOTM2(200),PENUTM(200),FRUITM(200),HSTPOM(200),HSTFRM(200),
     2           PEGSM2(200),ROTPM2,PNRIPM(200),BLOOMM(200),XLAI(200),
     3           IDAY(200),ROOTM2(200)
      COMMON /UCOM8/PROPOR(7),DAYADD
      COMMON /UCOM9/PENUTZ(7),FRUIT(7),HSTPOD(7),HSTFRT(7),PEGS(7),
     1          R(7),PNRIPE(7),PETWT(7)
      COMMON /UCOM10/XMATUR,PLTDAY
      COMMON /UCOM14/IMERSE(7)
      COMMON/UCOM15/STLFRT
      COMMON /UCOM21/PODWGT(7,200),MORE,BLOOMZ(7,200),KPEGST,
     1          PEGNO(7,200),PODST(7),PODCAP(7,200),AGEMAX(7,200),GRATEK,
     2          KPODST,GRRATE,PQPODS(7),PQNUTS(7),PODAGE(200)
      COMMON /UCOM23/STMMIN(7),STMLOS(7)
      COMMON /UCOM30/CONDEF,DEFTIM,NTYPE
      COMMON /UCOM34/EFFLAI(200)
      COMMON /UCOM40/STORE(200)
      DATA NDEX7/0/
C     SS(1) = EFFECTIVE LEAF AREA INDEX
C     SS(2) = PHYSIOLOGICAL DAY SINCE PLANTING DATE
C     SS(3) = REAL LEAF AREA INDEX
      IF (DTNOW.EQ.0.0) GO TO 950
      NOW = TNOW
      CALL WATERX
      IF (CLIMAT(NOW,6) - PLTDAY) 900,10,10
   10 IF (NDEX7.NE.0) GO TO 15
      PLTDAY = TNOW
      DEFTIM = 56.0
      ATRIB(1) = TNOW + DEFTIM
      ATRIB(2) = 1.
      CALL FILEM(1)
      NDEX7 = 1
   15 CALL PHZDAZ
      IF (NDEX2) 915,915,20
   20 CALL PTOTAL
```

```
      CALL PLTGRO
      ROTPM2 = 0.0
      PET = 0.0
      DO 50 J = 1,MERGE
      IF (IMERGE(J).LE.0) GO TO 50
      ROOTM2(NOW) = ROOTM2(NOW) + WTROOT(J) * PROPOR(J)
      STMM2(NOW) = STMM2(NOW) + WTSTEM(J) * PROPOR(J)
      STORE(NOW) = STORE(NOW) + (STMMIN(J) * PROPOR(J)) / 1000.
      WTLFM2(NOW) = WTLFM2(NOW) + WGHTLF(J) * PROPOR(J)
      GRPTSM(NOW) = GRPTSM(NOW) + AGRPTS(J) * PROPOR(J)
      XNOLFM(NOW) = XNOLFM(NOW) + XLEAFN(J) * PROPOR(J)
      PENUTM(NOW) = PENUTM(NOW) + PENUTZ(J) * PROPOR(J)
      FRUITM(NOW) = FRUITM(NOW) + FRUIT(J) * PROPOR(J)
      BLOOMM(NOW) = BLOOMM(NOW) + BLOOMZ(J,NOW) * PROPOR(J)
      HSTPOM(NOW) = HSTPOM(NOW) + HSTPOD(J) * PROPOR(J)
      HSTFRM(NOW) = HSTFRM(NOW) + HSTFRT(J) * PROPOR(J)
      PEGSM2(NOW) = PEGSM2(NOW) + PEGS(J) * PROPOR(J)
      ROTPM2 = ROTPM2 + R(J) * PROPOR(J)
      PNRIPM(NOW) = PNRIPM(NOW) + PNRIPE(J) * PROPOR(J)
      PET = PET + PETWT(7) * PROPOR(J)
   50 CONTINUE
      TOTM2(NOW) = STMM2(NOW) + WTLFM2(NOW) + FRUITM(NOW) + ROOTM2(NOW)
     1             + PET
      STLFRT = STMM2(NOW) + WTLFM2(NOW) + PET
      SS(1) = SSL(1) + DAYADD * DTNOW
      SS(3) = SSL(3) + DAYADD * DTNOW
      DAYADD = 0.0
      CALL RUTNUD
      CALL PNTLAI
      GO TO 100
  900 CONTINUE
      SS(2) = SSL(2)
  915 CONTINUE
      SS(1) = SSL(1)
      SS(3) = SSL(3)
  100 CONTINUE
      IDAY(NOW) = SS(2) + 0.5
      XLAI(NOW) = SS(3)
      EFFLAI(NOW) = SS(1)
  950 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE WATERX
      COMMON /GCOM2/ DD(100),DDL(100),DTFUL,DTNOW,ISEES,LFLAG(50),NFLAG,
     1NNEQD,NNEQS,NNEQT,SS(100),SSL(100),TTNEX
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1       ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM6/CLIMAT(200,6)
      COMMON /UCOM11/STRESF
      RETURN
      END
```

```
      SUBROUTINE PTOTAL
      DIMENSION AVGPTS(10)
      COMMON /GCOM1/ ATRIB(25),JEVNT,MFA,MFE(100),MLE(100),MSTOP,NCRDR,N
     1NAPO,NNAPT,NNATR,NNFIL,NNQ(100),NNTRY,NPRNT,PPARM(50,4),TNOW,TTBEG
     2,TTCLR,TTFIN,TTRIB(25),TTSET
      COMMON /GCOM2/ DD(100),DDL(100),DTFUL,DTNOW,ISEES,LFLAG(50),NFLAG,
     1NNEQD,NNEQS,NNEQT,SS(100),SSL(100),TTNEX
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1          ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM3/ISTEM(7,350),NODE(7,350),XLLAFN(7),SIZELF(7,200),
     1          WTLFAF(7,200),WTINOD(7,200),WTPET(7,200),AREALF(7),
     2          WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROOT(7),ICOUNT(7,350),
     3          PDAY(200),AGRPTS(7)
      COMMON /UCOM6/CLIMAT(200,6)
      COMMON /UCOM8/PROPOR(7),DAYAD)
      COMMON /UCOM10/XMATUR,PLTDAY
      COMMON /UCOM11/STRESF
      COMMON /UCOM12/PLTLAI,PTS
      COMMON /UCOM13/PN(200)
      COMMON /UCOM14/IMERGE(7)
      COMMON/UCOM15/STLFRT
      COMMON /UCOM16/PORT(7)
      COMMON /UCOM17/XLIMT(7)
      COMMON /UCOM18/ASPGEN(7)
      COMMON /UCOM31/ROOTF,SMAINF
      COMMON /UCOM33/PODLM,XLMMAZ
      DATA HSTCPY,STDECL,PTSSUM,AVGPTS,KAVG,AK/0.30,110.,0.0,10*0.0,6,
     1     0.0/
      DATA DECFCT/1.0/
      DATA PSLOPE,PTSFAC,RESPFC,BMETFC,PARFAC/0.836E-05,1.10,
     1     0.30,0.01,0.65/
      DATA AVG/5./
      DECRTE = (1.0 - HSTCPY)/(XMATUR - STDECL)
      DECST = TNOW - STDECL
      IF (DECST.LE.0.0) GO TO 9
      DECFCT = 1.0 - DECRTE * DECST
    9 CONTINUE
      PTS = PLTLAI * 1.0E4 * CLIMAT(NOW,1) * PSLOPE * PTSFAC
      PTS = PTS * STRESF * DECFCT
      PTS = PTS - PTS * RESPFC - BMETFC * STLFRT
      IF (PTS.LE.0.0) PTS = 0.0
      AK = AK + 1.
      AK = AMIN1 (AK,AVG)
      AVGPTS(1) = PTS
      PTSSUM = PTSSUM + AVGPTS(1) - AVGPTS(KAVG)
      PTSMEN = PTSSUM / AK
      KL = KAVG - 1
      DO 50 I = 1,KL
```

```
      L = KAVG - I + 1
   50 AVGPTS(L) = AVGPTS(L-1)
      XLMMAZ = AMAX1(PTSMEN,PODLM)
      IF (PODLM.GT.0.0) PODLM = XLMMAZ
      DO 110 J = 1,MERGE
      IF (IMERGE(J).LE.0) GO TO 110
      IF (SSL(3).LE.0.0) GO TO 15
      A = AREALF(J) / (SSL(3) * 10000.)
      GO TO 16
   15 A = PORT(J) / PROPOR(J)
   16 CONTINUE
      PTSYN(J) = PTS * A * 1000.
      XL = PARFAC * XLMMAZ * A * 1000.
      XN = PARFAC * PTS * A * 1000.
      IF (A.EQ.0.0) GO TO 90
      XLIMT(J) = AMAX1(XL,XN)
      IF (NDEX3.LT.2) XLIMT(J) = XN
   90 CONTINUE
      PTSRUT(J) = PTSYN(J) * SMAINF
      PTSYN(J) = PTSYN(J) - PTSRUT(J)
  100 ASPGST(J) = ASPGST(J) + ASPGEN(J)
  110 CONTINUE
      PN(NOW) = PTS
      RETURN
      END
```

```
      SUBROUTINE PLTGRO
      DIMENSION PEGDED(7)
      DIMENSION NEWREP(7,200)
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1        ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM2/HFTIME,TIMELF
      COMMON /UCOM4/ADDSTM
      COMMON /UCOM5/ISTEM(7,350),NODE(7,350),XLEAFN(7),SIZELF(7,200),
     1          WTLEAF(7,200),WTINOD(7,200),WTPET(7,200),AREALF(7),
     2          WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROOT(7),ICOUNT(7,350),
     3          PDAY(200),AGRPTS(7)
      COMMON /UCOM15/PENUTZ(7),FRUIT(7),HSTPOD(7),HSTFRT(7),PEGS(7),
     1          R(7),PNRIPE(7),PETWT(7)
      COMMON /UCOM17/XLIMT(7)
      COMMON /UCOM19/PHZDAY(200)
      COMMON /UCOM20/WANTLF(7),NUMBR(7),XINODE(7,200)
      COMMON /UCOM21/PODWGT(7,200),MORE,BLOOMZ(7,200),KPEGST,
     1          PEGNO(7,200),PODST(7),PODCAP(7,200),AGEMAX(7,200),GRATEK,
     2          KPODST,GRRATE,POPODS(7),PONUTS(7),PODAGE(200)
      COMMON /UCOM22/NEWVEG(7,200),ADDLF
      COMMON /  UCOM24/XNGNOD(7),NCOUNT(200),SURFAC(7,200),VEGGRO,
     2          VEGNIT,VEGNCR,ASVEGF,VEGCNR,PORLF,PORPT,PORNOD,SLW
      COMMON /UCOM26/WGTBNZ(7,200),PEANUT,RATIO,PTSS
      COMMON /UCOM27/PCTC,PODC,PCTN,PODN,ASPPRO,OILFAC
      COMMON /UCOM29/LCOUNT(7,350)
      COMMON /UCOM33/PODLM,XLMMAZ
      COMMON /UCOM35/NDEX6
      COMMON /UCOM37/NDEX9
      COMMON /UCOM43/WNTNUT(7),WNTPOD(7),WNTSTO(7),WNTSTM(7),AVLCON(7)
      COMMON /UCOM48/WANTBG(7)
      DATA SIZMIN,NEWREP,REPTIM,PODMAX,SIZRED/70.0,1400*0,6.0,1350.,
     1     .013/
      DATA CONS1/27.0/
      DATA NDEX11/0/
      DATA PEGDLD/740.0/
      MORROW = NOW + 1
      DO 50 J = 1,MERGE
      WANTBG(J) = 0.0
      WNTSTM(J) = 0.0
      WNTPOD(J) = 0.0
      WNTNUT(J) = 0.0
      WNTSTO(J) = 0.0
   50 WANTLF(J) = 0.0
      NYES = NOW - 1
      DO 200 I = 1,NYES
      PHZDAY(I) = PHZDAY(I) + DAYINC
      IF (PDAY(I).LE.0.0) GO TO 200
      PDAY(I) = PDAY(I) + DAYINC
```

```
      IF (PDAY(I).LT.HFTIME) GO TO 150
      DO 149 J = 1,MERGE
      NKEEP = WTLEAF(J,I)/SIZMIN * XINODE(J,I)
      XKEEP = NKEEP
      IF (XKEEP.GT.XINODE(J,I)) XKEEP = XINODE(J,1)
      XDROP = XINODE(J,1) - XKEEP
      N=NUMBR(J)
      IF (N) 149,149,118
  118 DO 149 K = 1,N
      IF (ISTEM(J,K).NE.7) GO TO 70
      IF (PDAY(I).LT.TIMELF) GO TO 70
      IF (ICOUNT(J,K).EQ.I) AGRPTS(J) = AGRPTS(J) - 1.
   70 CONTINUE
      IF (ISTEM(J,K).GE.5) GO TO 149
      IF (PDAY(I).LT.TIMELF) GO TO 10
      IF (LCOUNT(J,K) - 1) 149,121,149
  121 MN = ISTEM(J,K)
      NODE(J,K) = NODE(J,K) + 1
      L = NODE(J,K)
      IF (L-3) 143,122,122
  122 GO TO (123,130,140,146),MN
  123 IF (L-7) 126,148,143
  126 NUMBR(J) = NUMBR(J) + 1
      AGRPTS(J) = AGRPTS(J) + 1.
      ISTEM(J,NUMBR(J)) = 3
      NODE(J,NUMBR(J)) = 1
      ICOUNT(J,NUMBR(J)) = NOW
      XNLEAF(J,NOW) = XNLEAF(J,NOW) + 1.
      XINODE(J,NOW) = XINODE(J,NOW) + 1.
      GO TO 148
  130 IF (L-6) 141,125,142
  125 NUMBR(J) = NUMBR(J) + 1
      ISTEM(J,NUMBR(J)) = 5
      NODE(J,NUMBR(J)) = 1
      ICOUNT(J,NUMBR(J)) = NOW
      BLCOMZ(J,NOW) = BLCOMZ(J,NOW) + 1.
      IF (KPEGST.EQ.0) KPEGST = NOW
      GO TO 143
  141 IF (L-4) 143,148,143
  142 IF ((((L+1)/2)/2)*2 - ((L+1)/2)) 144,143,144
  143 NEWVEG(J,NOW) = NEWVEG(J,NOW) + 1
      IF (NDEX5.GT.0) GO TO 148
      NUMBR(J) = NUMBR(J) + 1
      AGRPTS(J) = AGRPTS(J) + 1.
      ISTEM(J,NUMBR(J)) = 4
      NODE(J,NUMBR(J)) = 1
      NEWVEG(J,NOW) = NEWVEG(J,NOW) - 1
      ICOUNT(J,NUMBR(J)) = NOW
```

```
      XNLEAF(J,NOW) = XNLEAF(J,NOW) + 1.
      XINODE(J,NOW) = XINODE(J,NOW) + 1.
      GO TO 148
  144 NEWREP(J,NOW) = NEWREP(J,NOW) + 1
      IF (NDEX3.EQ.2) GO TO 148
      NUMBR(J) = NUMBR(J) + 1
      ISTEM(J,NUMBR(J)) = 5
      NODE(J,NUMBR(J)) = 1
      ICOUNT(J,NUMBR(J)) = NOW
      NEWREP(J,NOW) = NEWREP(J,NOW) - 1
      BLOOMZ(J,NOW) = BLOOMZ(J,NOW) + 1.
      IF (KPEGST.EQ.0) KPEGST = NOW
      GO TO 148
  140 IF (L-6) 145,146,146
  145 IF (L-4) 143,144,143
  146 IF (((L/2)/2)*2 - (L/2)) 143,144,143
  143 CONTINUE
      LX = ICOUNT(J,K)
      IF (NDEX9.LT.1) GO TO 116
      IF (WTLEAF(J,I).LT.SIZMIN) GO TO 11
      GO TO 115
   10 IF (ICOUNT(J,K)-I) 120,115,120
  115 CONTINUE
      IF (LCOUNT(J,K).NE.0) GO TO 120
      IF (NDEX9.LT.1) GO TO 116
      LX = I
      IF (WTLEAF(J,I).LT.SIZMIN/3.0) GO TO 117
  116 CONTINUE
      LCOUNT(J,K) = ICOUNT(J,K)
      ICOUNT(J,K) = MORROW
      XNLEAF(J,MORROW) = XNLEAF(J,MORROW) + 1.
      XINODE(J,MORROW) = XINODE(J,MORROW) + 1.
      GO TO 120
   11 IF (XDROP.LE.0.01) GO TO 116
      XDROP = XDROP - 1.0
  117 ISTEM(J,K) = 6
      LCOUNT(J,K) = ICOUNT(J,K)
      AGRPTS(J) = AGRPTS(J) - 1.
      IF (WTLEAF(J,LX).GE.20.0) GO TO 120
      WTPET(J,LX) = WTPET(J,LX) / XNLEAF(J,LX)
      XNLEAF(J,LX) = XNLEAF(J,LX) - 1.0
      WTPET(J,LX) = WTPET(J,LX) * XNLEAF(J,LX)
      SIZELF(J,LX) = SIZELF(J,LX) - WTLEAF(J,LX)
      XINODE(J,LX) = XINODE(J,LX) - 1.0
  120 CONTINUE
  140 CONTINUE
  150 DO 160 J = 1,MERGE
      IF (PDAY(I).GE.HFTIME) WANTJG(J) = WANTJG(J)+XNLEAF(J,I)*ADDLF
```

```
     1          * DAYINC
 160 WANTLF(J) = WANTLF(J) + XNLEAF(J,I) * ADDLF * DAYINC
 200 CONTINUE
     PHZDAY(NOW) = DAYINC
     DO 210 J = 1,MERGE
     IF (XNLEAF(J,NOW).LT.0.01) GO TO 210
     PDAY(NOW) = DAYINC
     WANTLF(J) = WANTLF(J) + XNLEAF(J,NOW) * ADDLF * DAYINC
 210 CONTINUE
     IF (NDEX3 - 2) 300,500,300
 300 DO 350 J = 1,MERGE
     N = NUMBR(J)
     IF (N) 350,350,310
 310 DO 350 K = 1,N
     IF (ISTEM(J,K).NE.5) GO TO 350
     IF (NODE(J,K).GE.4) GO TO 350
     LL = ICOUNT(J,K)
     IF (PHZDAY(LL).LT.REPTIM) GO TO 350
     NODE(J,K) = NODE(J,K) + 1
     ICOUNT(J,K) = MORROW
     BLOOMZ(J,MORROW) = BLOOMZ(J,MORROW) + 1.
 350 CONTINUE
 500 CONTINUE
     IF (KPEGST.EQ.0) GO TO 600
     DO 501 J = 1,MERGE
 501 PEGS(J) = 0.0
     DO 510 K = KPEGST, NOW
     DO 510 J = 1,MERGE
     IF (BLOOMZ(J,K) - 0.01) 510,510,505
 505 IF (PHZDAY(K) - CONS1) 509,506,506
 506 PEGND(J,MORROW) = PEGND(J,MORROW) + BLOOMZ(J,K)
     BLOOMZ(J,K) = 0.0
     IF (PODST(J).LE.0.0) PODST(J) = MORROW
     RED = MORROW
     RED = RED - PODST(J)
     IF (KPODST.EQ.0) KPODST = NOW
     PODCAP(J,MORROW) = PODMAX - SIZRED * RED * PODMAX
     AGEMAX(J,MORROW) = 35.0 * 1.2
 509 PEGS(J) = PEGS(J) + BLOOMZ(J,K)
 510 CONTINUE
     IF (KPODST.EQ.0) GO TO 600
     GRRATE = GRATEK * DAYINC
     DO 512 J = 1,MERGE
     PQPODS(J) = 0.0
 512 PQNUTS(J) = 0.0
     DO 530 K = KPODST, NOW
     PODAGE(K) = PODAGE(K) + DAYINC
     DO 530 J = 1,MERGE
```

```
      IF (PEGNO(J,K).EQ.0.0) GO TO 530
      IF (PODWGT(J,K).GT.PODCAP(J,K)) GO TO 530
      PODSIZ = 0.17 * PODCAP(J,K)
      IF (PODAGE(K).GT.AGEMAX(J,K).AND.PODWGT(J,K).LT.PODSIZ) GO TO 527
      IF (PODWGT(J,K).LT.PODSIZ) GO TO 525
      IF (PODWGT(J,K).GT.0.8*PODCAP(J,K)) GO TO 526
  520 CONTINUE
      PQNUTS(J) = PQNUTS(J) + PEGNO(J,K) * GRRATE
      GO TO 530
  525 CONTINUE
      WANT1 = PODSIZ - PODWGT(J,K)
      WANT2 = (10.0 + 0.25 * PODWGT(J,K)) * DAYINC
      WANT = AMIN1(WANT1,WANT2)
      PQPODS(J) = PQPODS(J) + PEGNO(J,K) * WANT
      GO TO 530
  526 PQNUTS(J) = PQNUTS(J) + PEGNO(J,K) * GRRATE * 0.5
  527 CONTINUE
  530 CONTINUE
  600 CONTINUE
      DO 580 J = 1,MERGE
      WNTNUT(J) = PQNUTS(J) * PCTC / OILFAC
      WNTPOD(J) = PQPODS(J) * PODC
      IF (WNTNUT(J).LE.XLIMT(J)) GO TO 610
      PEGDED(J) = PEGDED(J) + 1.0
      WNTNUT(J) = XLIMT(J)
      WNTPOD(J) = 0.0
      IF (PEGDED(1).NE.5) GO TO 601
      PODLM = XLMMAZ
      NDEX3 = 2
      DO 60 K = KPEGST,MORROW
   60 BLOOMZ(J,K) = 0.0
  601 CONTINUE
  610 CONTINUE
  535 DO 540 I = 1,NOW
      IF (NCOUNT(I).EQ.0) GO TO 540
      IF (PHZDAY(I).GT.32.4) GO TO 540
      WNTSTM(J) = WNTSTM(J) + XINODE(J,1) * ADDSTM * DAYINC
  540 CONTINUE
      A = WANTLF(J) + WNTSTD(J) + WNTPOD(J) + WNTSTM(J)
      B = PTSYN(J) - WNTNUT(J)
      IF (NDEX1.LT.4) A = A - WANTLF(J)
      IF (NDEX1.LT.4) B = B - WANTLF(J)
      IF (A.LE.0.0001) GO TO 550
      AVLCON(J) = B / A
      GO TO 560
  550 AVLCON(J) = 0.0
  560 CONTINUE
      IF (AVLCON(J).GE.1.0) AVLCON(J) = 1.0
```

```
      IF (AVLCON(J).LE. 0.0) AVLCON(J) = 0.0
      IF (KPODST.GT.0.AND.AVLCON(J).EQ.0.0) PHZDAY(NOW) = 0.0
  580 CONTINUE
      IF (KPODST.NE.0) CALL DIVIDE
      CALL LEAVES
      IF (NDEX6.EQ.1) CALL GRPTS
      KK = 0
      DO 710 J = 1,MERGE
  710 IF (PTSYN(J).GT.0.001) KK = KK + 1
      IF (KK.NE.0) CALL STEMS
  900 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE LEAVES
      DIMENSION ADDOLD(7),ADD2(7)
      DIMENSION ADDRAT(7)
      COMMON /GCOM2/ DD(100),DDL(100),DTFUL,DTNOW,ISEES,LFLAG(50),NFLAG,
     1NNEQD,NNEQS,NNEQT,SS(100),SSL(100),TTNEX
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1        ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM2/HFTIME,TIMELF
      COMMON /UCOM5/ISTEM(7,350),NODE(7,350),XLEAFN(7),SIZELF(7,200),
     1          WTLEAF(7,200),WTINOD(7,200),WTPET(7,200),AREALF(7),
     2          WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROOT(7),ICOUNT(7,350),
     3        PDAY(200),AGRPTS(7)
      COMMON /UCOM3/PROPOR(7),DAYADD
      COMMON /UCOM7/PENUTZ(7),FRUIT(7),HSTPOD(7),HSTFRT(7),PEGS(7),
     1        R(7),PNRIPE(7),PETWT(7)
      COMMON /UCOM14/IMERGE(7)
      COMMON /UCOM20/WANTLF(7),NUMBR(7),XINODE(7,200)
      COMMON /UCOM23/STMMIN(7),STMLJS(7)
      COMMON / UCOM24/XNONOD(7),NCOUNT(200),SURFAC(7,200),VEGGRO,
     2        VEGNIT,VEGNCR,ASVEGF,VEGCNR,PORLF,PORPT,PORNOD,SLW
      COMMON /UCOM25/ASPREQ
      COMMON /UCOM43/WNTNUT(7),WNTPOD(7),WNTSTO(7),WNTSTM(7),AVLCON(7)
      COMMON /UCOM43/WANTBG(7)
      DO 450 J = 1,MERGE
      ADD2(J) = 0.0
      IF (WANTLF(J).LE.0.0) GO TO 446
      IF (NDEX1.GE.4) AVLLF = AVLCON(J) * WANTLF(J)
      IF (NDEX1.GE.4) GO TO 410
      AVLLF = AMIN1(WANTLF(J),PTSYN(J))
  410 CONTINUE
      IF (AVLLF.LT.0.0001) GO TO 445
      VEGGRO = AVLLF
  430 VEGNIT = VEGGRO * VEGNCR
      ASPREQ = VEGNIT * ASVEGF
      IF (ASPGST(J) .GE.ASPREQ) GO TO 440
      VEGNIT = ASPGST(J) / ASVEGF
      VEGGRO = VEGNIT * VEGCNR
      PTSYN(J) = PTSYN(J) - VEGGRO
      ASPGST(J) = 0.0
      PTSRUT(J) = PTSRUT(J) + PTSYN(J)
      PTSYN(J) = 0.0
      GO TO 445
  440 PTSYN(J) = PTSYN(J) - VEGGRO
      ASPGST(J) = ASPGST(J) - ASPREQ
  445 ADDRAT(J) = VEGGRO / WANTLF(J)
      GO TO 447
  446 ADDRAT(J) = 0.0
  447 CONTINUE
```

```
      IF (NDEX1.GE.3) GO TO 450
      IF (STMMIN(J).LE.0.0001) GO TO 450
      ADDOLD(J) = 1.0 - ADDRAT(J)
      WANTLF(J) = ADDOLD(J) * WANTBS(J)
      IF (WANTLF(J).LT.0.0001) GO TO 450
      ASPREQ = WANTLF(J) * VEGNCR + ASVEGF
      IF (ASPREQ.GT.ASPGST(J)) GO TO 450
      IF (STMMIN(J) - WANTLF(J)) 500,550,550
  500 VEGGRO = STMMIN(J)
      GO TO 600
  550 VEGGRO = WANTLF(J)
  600 CONTINUE
      WTSTEM(J) = WTSTEM(J) - VEGGRO/1000.
      STMMIN(J) = STMMIN(J) - VEGGRO
      ASPGST(J) = ASPGST(J) - VEGGRO * VEGNCR * ASVEGF
      ADD2(J) = VEGGRO / WANTLF(J) * ADDOLD(J)
  450 CONTINUE
      DO 480 I = 1,NOW
      IF (PDAY(I).LE.0.0) GO TO 480
      DO 460 J = 1,MERGE
      IF (IMERGE(J).LE.0) GO TO 460
      WTLEAF(J,I) = WTLEAF(J,I) + PORLF * ADDRAT(J) * DAYINC
      SIZELF(J,I) = SIZELF(J,I) + PORLF * ADDRAT(J) * DAYINC *
     1              XNLEAF(J,I)
      WTPET(J,I) = WTPET(J,I) + PORPT * ADDRAT(J) * XNLEAF(J,I) * DAYINC
      WTINOD(J,I) = WTINOD(J,I) + PORNOD * ADDRAT(J) * DAYINC
  460 CONTINUE
      IF (PDAY(I).LT.HFTIME) GO TO 480
      DO 455 J = 1,MERGE
      WTLEAF(J,I) = WTLEAF(J,I) + PORLF * ADD2(J) * DAYINC
      SIZELF(J,I) = SIZELF(J,I) + PORLF * ADD2(J) * DAYINC *
     1              XNLEAF(J,I)
      WTPET(J,I) = WTPET(J,I) + PORPT * ADD2(J) * XNLEAF(J,I) * DAYINC
      WTINOD(J,I) = WTINOD(J,I) + PORNOD * ADD2(J) * DAYINC
  455 CONTINUE
      IF (PDAY(I).LT.TIMELF) GO TO 480
      PDAY(I) = 0.0
      NCOUNT(I) = NOW
      DO 470 J = 1,MERGE
      IF (IMERGE(J).LE.0) GO TO 470
      SIZELF(J,I) = SIZELF(J,I) / 0.97
      XLEAFN(J) = XLEAFN(J) + XNLEAF(J,I)
      XNONOD(J) = XNONOD(J) + XINODE(J,I)
      SURFAC(J,I) = SIZELF(J,I) / SLW
      DAYADD = DAYADD + (SURFAC(J,I) * PROPOR(J)) / 10000.
      PETWT(J) = PETWT(J) + WTPET(J,I) / (1000. * 0.97)
      AREALF(J) = AREALF(J) + SURFAC(J,I)
      WGHTLF(J) = WGHTLF(J) + SIZELF(J,I) / 1000.
```

```
      WTSTEM(J) = WTSTEM(J) + (WTWOOD(J,I)*XNLEAF(J,I))/(1000.*.97)
  470 CONTINUE
  480 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DIVIDE
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDLX5,NOW,PTSYN(7),PTSRUT(7),
     1       ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM2/HFTIME,TIMELF
      COMMON /UCOM5/ISTEM(7,350),NODE(7,350),XLLAFN(7),SIZELF(7,200),
     1          WTLEAF(7,200),WTINOD(7,200),WTPET(7,200),AREALF(7),
     2          WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROOT(7),ICOUNT(7,350),
     3         PDAY(200),AGRPTS(7)
      COMMON /UCOM20/WANILF(7),NUMBR(7),XINODE(7,200)
      COMMON /UCOM21/PODWGT(7,200),MORE,BLOOMZ(7,200),KPEGST,
     1         PEGNO(7,200),PODST(7),PODCAP(7,200),AGEMAX(7,200),GRATEK,
     2         KPODST,GRRATE,PQPODS(7),PQNUTS(7),PODAGE(200)
      COMMON /UCOM22/NEWVEG(7,200),ADDLF
      COMMON /UCOM23/STMMIN(7),STMLIS(7)
      COMMON / UCOM24/XNONOD(7),NCOUNT(200),SURFAC(7,200),VEGGRO,
     2         VEGNIT,VEGNCR,ASVEGF,VEGCNR,PORLF,PORPT,PORNOD,SLW
      COMMON /UCOM25/ASPREQ
      COMMON /UCOM26/WGTBNZ(7,200),PEANUT,RATIO,PTSS
      COMMON /UCOM27/PCTC,PODC,PCTN,PODN,ASPPRO,OILFAC
      COMMON /UCOM31/ROOTF,SMAINF
      COMMON /UCOM43/WNTNUT(7),WNTPOD(7),WNTSTD(7),WNTSTM(7),AVLCON(7)
      DO 200 J = 1,MERGE
      FRUCHO = 0.0
      FRUNIT = 0.0
      PNTCHO = PQNUTS(J) * PCTC / OILFAC
      PODCHO = PQPODS(J) * PODC
      IF (WNTNUT(J) + WNTPOD(J).LE.0.001) GO TO 200
      IF (WNTNUT(J).LE.0.0001) GO TO 100
      IF (PTSYN(J) - WNTNUT(J)) 10,20,20
   10 IF (STMMIN(J)-WNTNUT(J)+PTSYN(J)) 15,16,16
   15 PTSYN(J) = PTSYN(J) + STMMIN(J)
      WTSTEM(J) = WTSTEM(J) - STMMIN(J) / 1000.
      STMMIN(J) = 0.0
      GO TO 20
   16 STMMIN(J) = STMMIN(J) - WNTNUT(J) + PTSYN(J)
      WTSTEM(J) = WTSTEM(J) - (WNTNUT(J) - PTSYN(J))/1000.
      PTSYN(J) = WNTNUT(J)
   20 IF (PTSYN(J).LE.0.0001) GO TO 200
      FRUCHO = AMIN1(PTSYN(J),WNTNUT(J))
      FRUNIT = (FRUCHO * OILFAC / PCTC) * PCTN
  100 FRUCHO = FRUCHO + AVLCON(J) * WNTPOD(J)
      IF (FRUCHO.LE.0.0001) GO TO 200
      FRUNIT = FRUNIT + AVLCON(J) * WNTPOD(J) * PODN
      FRUNCR = FRUNIT / FRUCHO
      FRUCNR = FRUCHO / FRUNIT
      ASPREQ = FRUNIT * ASPPRO
      IF (ASPGST(J).GT.ASPREQ) GO TO 110
      FRUCHO = (ASPGST(J) / ASPPRO) * FRUCNR
```

```
      FRUNIT = ASPGST(J) / ASPPRO
      ASPGST(J) = 0.0
      PTSRUT(J) = PTSRUT(J) + PTSYN(J) - FRUCHO
      PTSYN(J) = 0.0
      GO TO 115
  110 CONTINUE
      PTSYN(J) = PTSYN(J) - FRUCHO
      ASPGST(J) = ASPGST(J) - ASPRED
  115 CONTINUE
      PEANUT = FRUCHO
      IF (PODCHO) 120,120,119
  119 IF (FRUCHO - PNTCHO) 120,120,125
  120 RATIO = 1.0
      GO TO 130
  125 RATIO = (FRUCHO - PNTCHO) / PODCHO
  130 CONTINUE
      IF (RATIO.GT.1.0) RATIO = 1.0
      IF (RATIO.LE.0.0) RATIO = 0.0001
      CALL FRUFIL
      PTSYN(J) = PTSYN(J) + PTSS
      ASPGST(J) = ASPGST(J) + PTSS * FRUNCR
      PTSS = 0.0
  200 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FRUFIL
      DIMENSION PNRIPX(7),SHPCT(7,200),PEGROT(7,200)
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1       ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM9/PENUTZ(7),FRUIT(7),HSTPOD(7),HSTFRT(7),PEGS(7),
     1       R(7),PNRIPE(7),PETWT(7)
      COMMON /UCOM21/PODWGT(7,200),MORE,OLDUMZ(7,200),KPEGST,
     1       PEGNO(7,200),PODST(7),PODCAP(7,200),AGEMAX(7,200),GRATEK,
     2       KPODST,GRRATE,PQPODS(7),PQNUTS(7),PODAGE(200)
      COMMON /UCOM26/WGTBNZ(7,200),PEANUT,RATIO,PTSS
      COMMON /UCOM27/PCTC,PODC,PCTN,PODN,ASPPRO,OILFAC
      DATA AVLGRO,AVLGRX,PNRIPX,SHPCT,PEGROT,PEGLST/0.0,0.0,1407*0.0,
     1     1400*0.0,35.0/
      DATA PRIFAC/0.0/
      AVLGRO = PEANUT + AVLGRO
      GROW = RATIO**PRIFAC
      AVLGRX = 0.0
      PENUTZ(J) = 0.0
      HSTFRT(J) = 0.0
      HSTPOD(J) = 0.0
      FRUIT(J) = 0.0
      PNRIPX(J) = 0.0
      DO 11 K = KPODST, NOW
      IF (PEGNO(J,K).EQ.0.0) GO TO 11
      PODSIZ = 0.17 * PODCAP(J,K)
      IF (PODWGT(J,K).GT.PODCAP(J,K)) GO TO 20
      IF (PODAGE(K).GT.32.0.AND.PODWGT(J,K).LE.0.0001) GO TO 51
      IF (PODAGE(K).GT.AGEMAX(J,K).AND.PODWGT(J,K).LT.PODSIZ) GO TO 12
      IF (AVLGRX.EQ.1.0) GO TO 12
      IF (AVLGRO.LE.0.0) GO TO 12
      IF (PODWGT(J,K).LT.PODSIZ) GO TO 50
      PNTCHO = GRRATE * PEGNO(J,K) * PCTC / OILFAC
      IF (PODWGT(J,K).GT.0.3*PODCAP(J,K)) GO TO 35
      AVLGRO = AVLGRO - PNTCHO
      IF (AVLGRO.GE.0.0) GO TO 40
      Q = (PNTCHO + AVLGRO) / PNTCHO * GRRATE
   30 CONTINUE
      PODWGT(J,K) = PODWGT(J,K) + Q
      WGTBNZ(J,K) = WGTBNZ(J,K) + PEGNO(J,K) * Q
      AVLGRO = 0.0
      AVLGRX = 1.0
      GO TO 12
   35 PNTCHO = PNTCHO / 2.0
      GROTH = GRRATE / 2.0
      GO TO 55
   40 CONTINUE
      PODWGT(J,K) = PODWGT(J,K) + GRRATE
      WGTBNZ(J,K) = WGTBNZ(J,K) + GRRATE * PEGNO(J,K)
```

```
      GO TO 12
   50 CONTINUE
      WANT1 = PODSIZ - PODWGT(J,K)
      WANT2 = (10.0 + 0.25 * PODWGT(J,K)) * DAYINC
      WANT  = AMIN1(WANT1,WANT2)
      GROTH = WANT * GROW
      PNTCHD = GROTH * PEGNO(J,K) * PODC
   55 CONTINUE
      AVLGRO = AVLGRO - PNTCHD
      IF (AVLGRO.GE.0.0) GO TO 60
      Q = (PNTCHD + AVLGRO) / PNTCHD * GROTH
      GO TO 30
   60 CONTINUE
      PODWGT(J,K) = PODWGT(J,K) + GROTH
      WGTBNZ(J,K) = WGTBNZ(J,K) + GROTH * PEGNO(J,K)
      GO TO 12
   20 PNRIPX(J) = PNRIPX(J) + WGTBNZ(J,K) / 1000.
      PEGROT(J,K) = PEGROT(J,K) + 1.
      IF (PEGROT(J,K).LT.PEGLST) GO TO 12
      R(J) = R(J) + WGTBNZ(J,K) / 1000.
   51 SHPCT(J,K) = 0.0
      WGTBNZ(J,K) = 0.0
      PODWGT(J,K) = 0.0
      PEGNO(J,K) = 0.0
   12 CONTINUE
      IF (PODWGT(J,K).LE.0.0001) GO TO 11
      FRUIT(J) = FRUIT(J) + WGTBNZ(J,K) / 1000.
      PENUTZ(J) = PENUTZ(J) + PEGNO(J,K)
      IF (PODWGT(J,K).LT.PODSIZ) GO TO 11
      HSTPOD(J) = HSTPOD(J) + PEGNO(J,K)
      HSTFRT(J) = HSTFRT(J) + WGTBNZ(J,K) / 1000.
   11 CONTINUE
      IF (PNRIPC(J).GE.PNRIPX(J)) GO TO 65
      PNRIPC(J) = PNRIPX(J)
   65 CONTINUE
      PTSS = AVLGRO
      AVLGRO = 0.0
      RETURN
      END
```

```
      SUBROUTINE GRPTS
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1       ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM5/ISTEM(7,350),NODE(7,350),XLEAFN(7),SIZELF(7,200),
     1       WTLEAF(7,200),WTINOD(7,200),WTPET(7,200),AREALF(7),
     2       WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROOT(7),ICOUNT(7,350),
     3       PDAY(200),AGRPTS(7)
      COMMON /UCOM7/STMM2(200),WTLFM2(200),GRPTSM(200),XNOLFM(200),
     1       TOTM2(200),PENUFM(200),FRUITM(200),HSTPOM(200),HSTFRM(200),
     2       PEGSM2(200),ROTPM2,PNRIPM(200),BLOOMM(200),XLAI(200),
     3       IDAY(200),ROOTM2(200)
      COMMON /UCOM3/PROPOR(7),DAYADD
      COMMON /UCO420/WANILF(7),NUMBR(7),XINODE(7,200)
      COMMON /UCO422/NEWVEG(7,200),ADDLF
      COMMON / UCOM24/XNONOD(7),NCOUNT(200),SURFAC(7,200),VEGGRO,
     2       VEGNIT,VEGNCR,ASVEGF,VEGCNR,PORLF,PORPT,PORNOD,SLW
      COMMON /UCOM36/PLTPOP
      COMMON /UCOM43/WHTNUT(7),WNTPOD(7),WNTSTD(7),WNTSTM(7),AVLCON(7)
      P = 333.0 - GRPTSM(NOW-1)
      DO 200 J = 1,MERGE
      IF (PTSYN(J).LT.0.001) GO TO 200
      KK = NOW - 2
      SUM = 0.0
      ISUM = 0
      IF (P) 200,200,5
    5 CONTINUE
      DO 10 I = KK, NOW
   10 ISUM = ISUM + NEWVEG(J,I)
      SUM = ISUM
      XI = SUM * PROPOR(J)
      IF (XI - P) 16,15,15
   15 CONTINUE
      SUM = AINT(P/PROPOR(J))
      NDEX6 = 2
   16 CONTINUE
      IF (SUM.LE.0.1) GO TO 200
      A = SUM * ADDLF * DAYINC
      X = SUM
      LL = SUM
      IF (PTSYN(J) - A) 30,20,20
   20 B = ADDLF * VEGNCR * ASVEGF * SUM * DAYINC
   25 IF (ASPGST(J) - B) 40,50,50
   30 LL = (PTSYN(J) / A) * SUM
      X = LL
      B = ADDLF * VEGNCR * ASVEGF * X * DAYINC
      IF (B.LE.0.0) GO TO 170
      A = X * ADDLF * DAYINC
      GO TO 25
```

```
40 LL = (ASPGST(J) / B) * X
   X = LL
   B = ADDLF * VEGNCR * ASVEGF * X * DAYINC
   A = X * ADDLF * DAYINC
50 IF (LL) 170,170,55
55 PTSYN(J) = PTSYN(J) - A
   ASPGST(J) = ASPGST(J) - B
   WTLEAF(J,NOW) = PORLF * DAYINC
   SIZELF(J,NOW) = SIZELF(J,NOW) + PORLF * X * DAYINC
   WTPET(J,NOW) = WTPET(J,NOW) + PORPT * X * DAYINC
   WTINOD(J,NOW) = PORNOD * DAYINC
   XINODE(J,NOW) = XINODE(J,NOW) + X
   XNLEAF(J,NOW) = XNLEAF(J,NOW) + X
   AGRPTS(J) = AGRPTS(J) + X
   PDAY(NOW) = DAYINC
   DO 70 JK = 1,LL
   NUMBR(J) = NUMBR(J) + 1
   ISTEM(J,NUMBR(J)) = 4
   NODE(J,NUMBR(J)) = 1
   ICOUNT(J,NUMBR(J)) = NOW
70 CONTINUE
   DO 165 I = KK,NOW
   M = NEWVEG(J,I)
   IF (M.EQ.0) GO TO 165
   DO 160 JK = 1,M
   IF (LL) 170,170,155
155 LL = LL - 1
   NEWVEG(J,I) = NEWVEG(J,I) - 1
160 CONTINUE
165 CONTINUE
170 CONTINUE
   P = P - X * PROPOR(J)
200 CONTINUE
   RETURN
   END
```

```
      SUBROUTINE STEMS
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1       ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM4/ADDSTM
      COMMON /UCO45/ISTEM(7,350),NODE(7,350),XLEAFN(7),SIZELF(7,200),
     1         WTLEAF(7,200),WTINOD(7,200),WTPET(7,200),AREALF(7),
     2         WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROOT(7),ICOUNT(7,350),
     3       PDAY(200),AGRPTS(7)
      COMMON /UCOM10/PHZDAY(200)
      COMMON /UCO420/WANTLF(7),NUMOR(7),XINODE(7,200)
      COMMON /UCO421/PODWGT(7,200),MORE,BLOOMZ(7,200),KPEGST,
     1       PEGNO(7,200),PODST(7),PODCAP(7,200),AGEMAX(7,200),GRATEK,
     2       KPODST,GRRATE,PQPODS(7),PQNUTS(7),PODAGE(200)
      COMMON /UCO423/STMMIN(7),STMLOS(7)
      COMMON / UCO424/XNONOD(7),NCOUNT(200),SURFAC(7,200),VEGGRO,
     2       VEGNIT,VEGNCR,ASVEGF,VEGCNR,PORLF,PORPT,PORNOD,SLW
      COMMON /UCOM25/ASPREQ
      COMMON /UCO443/WNTNUT(7),WNTPOD(7),WNTSTO(7),WNTSTM(7),AVLCON(7)
      DO 600 J = 1,MERGE
      VEGGRO = PTSYN(J)
      IF (PTSYN(J).LT.0.001) GO TO 600
  200 VEGNIT = VEGGRO * VEGNCR
      ASPREQ = VEGNIT * ASVEGF
      IF (ASPGST(J).GE.ASPREQ) GO TO 300
      VEGNIT = ASPGST(J) / ASVEGF
      VEGGRO = VEGNIT * VEGCNR
      PTSYN(J) = PTSYN(J) - VEGGRO
      ASPGST(J) = 0.0
      PTSRUT(J) = PTSRUT(J) + PTSYN(J)
      PTSYN(J) = 0.0
      GO TO 400
  300 PTSYN(J) = PTSYN(J) - VEGGRO
      ASPGST(J) = ASPGST(J) - ASPREQ
  400 A = (VEGGRO + VEGNIT) / 0.97
      WTSTEM(J) = WTSTEM(J) + A / 1000.
      STORE = A - (WNTSTM(J)*AVLCON(J))*(1.0+VEGNCR) / 0.97
      STORE = AMAX1(STORE,0.0)
      STMMIN(J) = STMMIN(J) + STORE
      C = XNONOD(J) * 40.0
      IF (STMMIN(J).LE.C) GO TO 600
      WTSTEM(J) = WTSTEM(J) + (C - STMMIN(J))/1000.
      STMMIN(J) = C
  600 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PNTLAI
      COMMON /GCOM2/ DD(100),DDL(100),DTFUL,DTNOW,ISFES,LFLAG(5)),NFLAG,
     1NNEQD,NNEQS,NNEQT,SS(100),SSL(100),TTNEX
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1       ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM12/PLTLAI,PTS
      COMMON /UCOM32/AMTLT(200)
      IF (NDEX1.LT.2) GO TO 10
      PLTLAI = (11.767 + 27.167 * SS(1) - 2.192 * SS(1) * SS(1))/100.
      GO TO 20
   10 PLTLAI = SS(1)
   20 AMTLT(NOW) = PLTLAI * 100. + 1.05
      RETURN
      END
```

```
      SUBROUTINE PHZDAZ
      COMMON /GCD42/ DD(100),DDL(100),DTFUL,DTNOW,ISEES,LFLAG(50),NFLAG,
     1NNEQD,NNEQS,NNEQT,SS(100),SSL(100),TTNEX
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1       ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCD46/CLIMAT(200,6)
      REAL MAX, MIN
      DATA SETMIN,TMPOPT,DAYDEG/50.0,90.0,25.0/
      MAX = CLIMAT(NOW,2)
      MIN = CLIMAT(NOW,3)
      IF (MIN.LT.SETMIN) MIN = SETMIN
      IF (MAX.LT.SETMIN) MAX = SETMIN
      IF (MAX.GT.TMPOPT) MAX = TMPOPT
      DEGREZ = (MAX + MIN) / 2.0 - SETMIN
      DAYINC = DEGREZ / DAYDEG
      SS(2) = SSL(2) + DAYINC * DTNOW
      RETURN
      END
```

```
      SUBROUTINE RUTNOD
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1       ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM5/ISTEM(7,350),NODE(7,350),XLEAFN(7),SIZELF(7,200),
     1        WTLEAF(7,200),WTINOD(7,200),WTPET(7,200),AREALF(7),
     2        WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROOT(7),ICOUNT(7,350),
     3       PDAY(200),AGRPTS(7)
      COMMON /UCOM18/ASPGEN(7)
      COMMON /UCOM31/ROOTF,SMAINF
      DATA EFFEXN/1.0/
      DO 10 J = 1,MERGE
      PDROOT = PTSRUT(J) * ROOTF
      PDNOD = PTSRUT(J) - PDROOT
      ASPGEN(J) = PDNOD * EFFEXN
   10 WTROOT(J) = WTROOT(J) + PDROOT / 1000.
      RETURN
      END
```

```
      SUBROUTINE ATTAC
      DIMENSION AGELAR(7)
      DIMENSION SUMLAR(7)
      COMMON /GCOM1/ ATRIB(25),JEVNT,MFA,MFE(100),MLE(100),MSTOP,NCRDR,N
     1NAPO,NNAPT,NNATR,NNFIL,NNQ(100),NNTRY,NPRNT,PPARM(50,4),TNOW,TTBEG
     2,TTCLR,TTFIN,TTRIB(25),TTSET
      COMMON /GCOM2/ DD(100),DDL(100),DTFUL,DTNOW,ISEES,LFLAG(50),NFLAG,
     1NNEQD,NNEQS,NNEQT,SS(100),SSL(100),TTNEX
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1        ASPSST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM5/ISTEM(7,350),NODE(7,350),XLEAFN(7),SIZELF(7,200),
     1          WTLEAF(7,200),WTINOD(7,200),WTPET(7,200),AREALF(7),
     2          WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROUT(7),ICOUNT(7,350),
     3        PDAY(200),AGRPTS(7)
      COMMON /UCOM3/PROPOR(7),DAYADD
      COMMON/UCOM12/PLTLAI,PTS
      COMMON / UCOM24/XNONOD(7),NCOUNT(200),SURFAC(7,200),VEGGRO,
     2        VEGNIT,VEGNCR,ASVEGF,VEGCNR,PORLF,PORPT,PORNOD,SLW
      COMMON /UCOM30/CONDEF,DEFTIM,NTYPE
      COMMON /UCOM60/TOTEAT
      DATA AGELAR/7*0.0/
      DATA SUMLAR/20.0,6*0.0/
      DATA A/0.011/
      DATA B/2.993/
      DATA CONSUM/0.0/
      EATEN = 0.0
      DO 10 J = 1,MERGE
      AGELAR(J) = AGELAR(J) + 1.0
      IF (AGELAR(J).GE.27.0) GO TO 10
      EATEN = EATEN + A * SUMLAR(J) * AGELAR(J)**B * PROPOR(J)
   10 CONTINUE
      CONSUM = EATEN - TOTEAT
      IF (CONSUM.LE.0.0) CONSUM = 0.0
      TOTEAT = TOTEAT + CONSUM
      IF (SS(3).LE.0.0) GO TO 15
      CONDEF = 1.0 - (CONSUM / (SS(3) * 10000.))
      GO TO 16
   15 CONTINUE
      CONDEF = 0.0
   16 CONTINUE
      IF (CONDEF.LT.0.0) CONDEF = 0.0
      KK = 0
      DO 20 J = 1,MERGE
      IF (SUMLAR(J).EQ.0.0) GO TO 20
      IF (AGELAR(J).GE.27.0) GO TO 20
      KK = KK + 1
   20 CONTINUE
      IF (KK) 40,40,30
```

```
30  CALL INSECT
    ATRIB(1) = TNOW + 1.0
    ATRIB(2) = 1.
    CALL FILEM(1)
40  CONTINUE
    RETURN
    END
```

```
      SUBROUTINE INSECT
      COMMON /GCOM1/ ATRIB(25),JEVNT,MFA,MFE(100),MLE(100),MSTOP,NCRDR,N
     1NAPO,NNAPT,NNATR,NNFIL,NNQ(100),NNTRY,NPRNT,PPARM(50,4),TNOW,TTBEG
     2,TTCLR,TTFIN,TTRIB(25),TTSET
      COMMON /GCOM2/ DD(100),DDL(100),DTFUL,DTNOW,ISEES,LFLAG(50),NFLAG,
     1NNEQD,NNEQS,NNEQT,SS(100),SSL(100),TTNEX
      COMMON /GCOM3/ AAERR,DTMAX,DTMIN,DTSAV,IITES,LLERR,LLSAV,LLSEV,RRE
     1PR,TTLAS,TTSAV
      COMMON /GCOM4/ DTPLT(10),HHLOW(25),HHWID(25),IICRD,IITAP(10),JJCEL
     1(500),LLABC(25,2),LLABH(25,2),LLABP(11,2),LLABT(25,2),LLPH1(10),LL
     2PLO(10),LLPLT,LLSUP(15),LLSYM(10),MMPTS,NNCEL(25),NNCLT,NNHIS,NNPL
     3T,NNPTS(10),NNSTA,NNVAR(10),PPHI(10),PPLO(10)
      COMMON /GCOM5/ IIEVT,IISED(6),JJBEG,JJCLR,MMNIT,MMON,NNAME(3),NNCF
     1I,NNDAY,NNPT,NNSET,NNPRJ,NNPR4,NNRNS,NNRUN,NNSTR,NNYR,SSEED(6)
      COMMON /GCOM6/ EENQ(100),IINN(100),KKRNK(100),MMAXQ(100),QQTIM(100
     1),SSOBV(25,5),SSTPV(25,6),VVAQ(100)
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1         ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM2/HFTIME,TIMELF
      COMMON /UCOM5/ISTEM(7,350),NODE(7,350),XLEAFN(7),SIZELF(7,200),
     1          WTLEAF(7,200),WTINOD(7,200),WTPET(7,200),AREALF(7),
     2          WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROOT(7),ICOUNT(7,350),
     3         PDAY(200),AGRPTS(7)
      COMMON /UCOM8/PROPOR(7),DAYADD
      COMMON/UCOM12/PLTLAI,PTS
      COMMON /UCOM20/WANTLF(7),NUMBR(7),XINODE(7,200)
      COMMON /UCOM22/NEWVEG(7,200),ADDLF
      COMMON / UCOM24/XNONOD(7),NCOUNT(200),SURFAC(7,200),VEGGRO,
     2         VEGNIT,VEGNCR,ASVEGF,VEGCHR,PURLF,PORPT,PURNOD,SLW
      COMMON /UCOM29/LCOUNT(7,350)
      COMMON /UCOM30/CONDEF,DEFTIM,NTYPE
      COMMON /UCOM51/CONGRO
      DATA IDAM/0/
      DATA  PLTMAX/0.0/
      XY = PLTLAI * 0.6
      PLTMAX = AMAX1(PLTMAX,XY)
      DEFPER = (1.0 - CONDEF) * 100.
      NOW = TNOW
      MORROW = NOW + 1
      IF (CONGRO.EQ.0.0) GO TO 9
      M = 1.0/CONGRO
    9 CONTINUE
      IF (NTYPE - 2) 10,50,10
   10 DO 20 J = 1,MERGE
      WGHTLF(J) = WGHTLF(J) * CONDEF
      AREALF(J) = AREALF(J) * CONDEF
      DO 20 I = 1,NOW
      IF (NCOUNT(I).EQ.0) GO TO 20
```

```
      SIZELF(J,I) = SIZELF(J,I) * CONDEF
      WTLEAF(J,I) = WTLEAF(J,I) * CONDEF
      SURFAC(J,I) = SURFAC(J,I) * CONDEF
   20 CONTINUE
      SS(3) = SS(3) * CONDEF
   50 IF (NTYPE - 2) 140,55,100
   55 ALEFT = 0.0
      DO 95 J = 1,MERGE
      AMTDEF = AREALF(J) * CONDEF
      DO 90 I = 1,NOW
      JK = NOW - I + 1
      IF (NCOUNT(JK).EQ.0) GO TO 90
      C1 = SURFAC(J,JK)
      C2 = AREALF(J) - C1
      IF (C2.LT.AMTDEF) GO TO 60
      WTLEAF(J,JK) = 0.0
      WGHTLF(J) = WGHTLF(J) - SIZELF(J,JK) / 1000.
      SIZELF(J,JK) = 0.0
      AREALF(J) = AREALF(J) - SURFAC(J,JK)
      SURFAC(J,JK) = 0.0
      GO TO 90
   60 C2 = AREALF(J) - AMTDEF
      C3 = 1.0 - C2/SURFAC(J,JK)
      SURFAC(J,JK) = SURFAC(J,JK) - C2
      WGHTLF(J) = WGHTLF(J) - SIZELF(J,JK) / 1000.
      SIZELF(J,JK) = SIZELF(J,JK) * C3
      WTLEAF(J,JK) = WTLEAF(J,JK) * C3
      WGHTLF(J) = WGHTLF(J) + SIZELF(J,JK) / 1000.
      AREALF(J) = AMTDEF
      GO TO 91
   90 CONTINUE
   91 CONTINUE
      ALEFT = ALEFT + (AREALF(J) * PROPOR(J))/10000.
   95 CONTINUE
      SS(3) = ALEFT
      GO TO 140
  100 CONTINUE
      DO 130 J = 1,MERGE
      N = NUMBR(J)
      DO 125 I = 1,NOW
      IF (NCOUNT(I).NE.0) GO TO 125
      IF (XNLEAF(J,I).LE.0.01) GO TO 125
      DO 120 K = 1,N,M
      IF (ISTEM(J,K).GE.5) GO TO 120
      IF (ICOUNT(J,K).NE.I) GO TO 120
      SIZELF(J,I) = SIZELF(J,I) - WTLEAF(J,I)
      WTPET(J,I) = WTPET(J,I) / XNLEAF(J,I)
      XNLEAF(J,I) = XNLEAF(J,I) - 1.0
```

```
      XINODE(J,I) = XINODE(J,I) - 1.0
      WTPET(J,I) = WTPET(J,I) * XNLEAF(J,1)
      AGRPTS(J) = AGRPTS(J) - 1.0
      L = LCOUNT(J,K)
      IF (L.EQ.0) GO TO 115
      SIZELF(J,L) = SIZELF(J,L) - WTLEAF(J,L)
      WTPET(J,L) = WTPET(J,L) / XNLEAF(J,L)
      XNLEAF(J,L) = XNLEAF(J,L) - 1.0
      XINODE(J,L) = XINODE(J,L) - 1.0
      WTPET(J,L) = WTPET(J,L) * XNLEAF(J,L)
  115 MN = ISTEM(J,K)
      ISTEM(J,K) = 6
      L = NODE(J,K)
  114 GO TO (116,117,118,119),MN
  116 NUMBR(J) = NUMBR(J) + 1
      AGRPTS(J) = AGRPTS(J) + 1.0
      ISTEM(J,NUMBR(J)) = 4
      IF (L.LE.4.AND.MN.EQ.1) ISTEM(J,NUMBR(J)) = 3
      NODE(J,NUMBR(J)) = 1
      ICOUNT(J,NUMBR(J)) = MORROW
      XNLEAF(J,MORROW) = XNLEAF(J,MORROW) + 1.
      XINODE(J,MORROW) = XINODE(J,MORROW) + 1.
      GO TO 121
  117 IF (L.LE.6.AND.L.NE.2) GO TO 116
      IF ((((L+1)/2)/2)*2-((L+1)/2)) 121,116,121
  118 IF (L.LT.6.AND.L.NE.2) GO TO 116
  119 IF (((L/2)/2)*2-(L/2)) 121,116,121
  121 IF (L.NE.NODE(J,K)) GO TO 120
      L = NODE(J,K) - 1
      IF (L.NE.0) GO TO 114
  120 CONTINUE
  125 CONTINUE
  130 CONTINUE
  140 CONTINUE
      IF (NTYPE - 2) 200,150,200
  150 CONTINUE
      SS(I) = SS(J)
      GO TO 300
  200 Y = 99.45 - 0.0715 * DEFPER - 0.00816*DEFPER*DEFPER
      Y = PLTLAI * Y
      IF (Y.LE.16.1) GO TO 250
      Y = Y - 11.767
      SS(1) = (27.167 - SQRT(27.167**2 - 4.0*2.192*Y))/(2.*2.192)
      GO TO 300
  250 SS(1) = Y / 100.
  300 CALL PNTLAI
      IF (PLTLAI.LE.PLTMAX) IDAM = 1
      IF (IDAM) 400,400,350
```

```
350 CONTINUE
    KK = NOW - 2
    DO 390 J = 1,MERGE
    ISUM = 0
    DO 360 I = KK,NOW
    ISUM = ISUM + NEWVEG(J,I)
    NEWVEG(J,I) = 0
360 CONTINUE
    IF (ISUM.LE.0) GO TO 390
    DO 370 JK = 1,ISUM
    NUMBR(J) = NUMBR(J) + 1
    ISTEM(J,NUMBR(J)) = 7
    NODE(J,NUMBR(J)) = 1
    ICOUNT(J,NUMBR(J)) = MORROW
    XNLEAF(J,MORROW) = XNLEAF(J,MORROW) + 1.
    AGRPTS(J) = AGRPTS(J) + 1.
370 CONTINUE
390 CONTINUE
400 CONTINUE
    RETURN
    END
```

```
      SUBROUTINE OTPUT
      COMMON /UCOM7/STMM2(200),WTLFM2(200),GRPTSM(200),XNOLFM(200),
     1       TOTM2(200),PENUTM(200),FRUITM(200),HSTPDM(200),HSTFRM(200),
     2        PEGSM2(200),ROTPM2,PNRIPM(200),BLOOMM(200),XLAI(200),
     3        IDAY(200),ROOTM2(200)
      COMMON /UCOM10/XMATUR,PLTDAY
      COMMON /UCOM13/PN(200)
      COMMON /UCOM28/TTL(20)
      COMMON /UCOM30/CONDEF,DEFTIM,ITYPE
      COMMON /UCOM32/AMTLT(200)
      COMMON /UCOM34/EFFLAI(200)
      COMMON /UCOM40/STORE(200)
       COMMON /UCOM51/CONGRO
      COMMON /UCOM60/TOTEAT
      WRITE(6,10) TTL
   10 FORMAT (1H1////20X,20A4//)
      WRITE (6,20)
   20 FORMAT(70X,'----------------PEANUTS----------------')
      WRITE (6,30)
   30 FORMAT(6X,'PHYS',2X,'NET',3X,'---LEAVES----',3X,'STEM',3X,
     1       'GROW',3X,'DAILY',3X,'STORE   TOTAL',3X,'TOTAL',4X,'RIPE',
     2       3X,'HARV.',2X,'HARV.',3X,'TOTAL')
      WRITE (6,40)
   40 FORMAT(1X,'DAY',2X,'DAY',3X,'LAI',4X,'PTS',4X,'NO.',3X,'WEIGHT',
     1       2X,'WEIGHT',2X,'PTS',3X,'FLOWERS',2X,'CARB',3X,'NUMBER',2X,
     2       'WEIGHT',2X,'WEIGHT',3X,'NO.',3X,'WEIGHT',2X,'WEIGHT')
      WRITE (6,50)
   50 FORMAT (1X,'---',2X,'----',2X,'----',2X,'-----',2X,'-----',2X,
     1       '------',2X,'------',2X,'----',2X,'--------',2X,'-----',
     2       3(2X,'------'),2X,'-----',2X,'------',2X,'-------'/)
      K = 0
      LJ = PLTDAY
      M = XMATUR + PLTDAY
      DO 100 I = LJ,M
      WRITE (6,60) K,IDAY(I),XLAI(I),PN(I),XNOLFM(I),WTLFM2(I),
     1       STMM2(I),GRPTSM(I),BLOOMM(I),STORE(I),PENUTM(I),
     2       FRUITM(I),PNRIPM(I),HSTPDM(I),HSTFRM(I),TOTM2(I)
   60 FORMAT (1X,I3,2X,I3,3X,F4.2,2X,F5.2,1X,F6.1,2X,F6.2,2X,F6.2,1X,
     1       F6.1,2X,F5.1,2X,F6.1,2X,F6.1,2X,F6.2,2X,F6.2,2X,F5.1,2X,
     2       F6.2,2X,F7.2)
      K = K + 1
  100 CONTINUE
      WRITE (6,70)
   70 FORMAT(1H1////20X,'DAY',5X,'REAL LAI',5X,'EFFECTIVE LAI',5X,
     1       'LIGHT INTERCEPTION'/)
      K = 0
      DO 150 I = LJ,M
      WRITE (6,80) K,XLAI(I),EFFLAI(I),AMTLT(I)
```

```
 30 FORMAT(20X,I3,7X,F4.2,11X,F4.3,16X,F6.2)
    K = K + 1
150 CONTINUE
    FACTOR = (1.0 - CONDEF) * 100.
    CONGRO = CONGRO * 100.
    WRITE (6,250) FACTOR,DEFTIM,NTYPE
250 FORMAT (1X////20X,'PERCENT DEFOLIATION =',F10.1/20X,
   1          'DAYS FROM PLANTING TO START OF DEFOLIATION =',F6.0/
   2          20X,'TYPE OF DEFOLIATION =',I3///)
    WRITE (6,255) CONGRO
255 FORMAT (20X,'PERCENT OF GROWING TIPS REMOVED =',F10.1///)
    WRITE (6,260)
260 FORMAT(20X,'TYPE1 DEFOLIATION MEANS UNIFORM THROUGHOUT THE CANOPY'
   1          /20X,'TYPE 2 MEANS OUTER PORTION OF CANOPY ONLY'/
   2          20X,'TYPE 3 MEANS UNIFORM DEFOLIATION OF FULLY DEVELOPED
   3LEAVES AND DEVELOPING LEAVES AND GROWING POINTS')
    WRITE (6,270) TOTEAT
270 FORMAT(20X,'TOTAL FOLIAGE CONSUMED BY LARVAE, CM2 =',F12.2)
    RETURN
    END
```

```
      BLOCK DATA
      COMMON /UCOM1/NDEX1,NDEX2,NDEX3,NDEX5,NOW,PTSYN(7),PTSRUT(7),
     1       ASPGST(7),DAYINC,J,MERGE,MORROW
      COMMON /UCOM2/HFTIME,TIMLF
      COMMON /UCOM5/ISTEM(7,350),NODE(7,350),XLEAFN(7),SIZELF(7,200),
     1        WTLEAF(7,200),WTINOD(7,200),WTPET(7,200),AREALF(7),
     2        WGHTLF(7),WTSTEM(7),XNLEAF(7,200),WTROOT(7),ICOUNT(7,350),
     3       PDAY(200),AGRPTS(7)
      COMMON /UCOM7/STMM2(200),WTLF42(200),SEPTSM(200),XNOLFM(200),
     1       TOTM2(200),PENUTM(200),FRUITM(200),HSTPDM(200),HSTFRM(200),
     2        PEGSM2(200),ROTPM2,PNRIPM(200),BLOCMM(200),XLAI(200),
     3        IDAY(200),ROOTM2(200)
      COMMON /UCOM8/PROPOR(7),DAYA))
      COMMON /UCOM9/PENUTZ(7),FRUIT(7),HSTPOD(7),HSTFRT(7),PEGS(7),
     1       R(7),PNRIPE(7),PETWT(7)
      COMMON /UCOM10/XMATUR,PLTDAY
      COMMON /UCOM11/STRESF
      COMMON /UCOM12/PLTLAI,PTS
      COMMON /UCOM13/PN(200)
      COMMON / UCOM14/IMERGE(7)
      COMMON/UCOM15/STLFRT
      COMMON /UCOM16/PORT(7)
      COMMON /UCOM17/XLIMT(7)
      COMMON /UCOM18/ASPGEN(7)
      COMMON /UCOM19/PHZDAY(200)
      COMMON /UCOM20/WANTLF(7),NUMBR(7),XINODE(7,200)
      COMMON /UCOM21/PODWGT(7,200),AGRE,BLOOMZ(7,200),KPEGST,
     1       PEGNO(7,200),PODST(7),PODCAP(7,200),AGEMAX(7,200),GRATEK,
     2       KPODST,GRRATE,PQPODS(7),PQNUTS(7),PODAGE(200)
      COMMON /UCOM22/NEWVEG(7,200),ADDLF
      COMMON /UCOM23/STMMIN(7),STMLOS(7)
      COMMON / UCOM24/XNONOD(7),NCOUNT(200),SURFAC(7,200),VEGGRO,
     2       VEGNIT,VEGNCR,ASVEGF,VEGCNR,PORLF,PORPT,PORNOD,SLW
      COMMON /UCOM26/WGTBNZ(7,200),PEANUT,RATIO,PTSS
      COMMON /UCOM29/LCOUNT(7,350)
      COMMON /UCOM30/CONDEF,DEFTIM,NTYPE
      COMMON /UCOM31/ROUTF,SMAINF
      COMMON /UCOM32/AMTLT(200)
      COMMON /UCOM33/PODLM,XLMMAZ
      COMMON /UCOM34/EFFLAI(200)
      COMMON /UCOM35/NDEX6
      COMMON /UCOM37/NDEX9
      COMMON /UCOM40/STORE(200)
       COMMON /UCOM51/CONGRO
      COMMON /UCOM60/TOTEAT
      DATA TOTEAT/0.0/
      DATA PLTDAY/144./
      DATA STRESF/1.0/
```

```
      DATA NDEX1,NDEX2,NDEX3,NDEX5,PTSYN,PTSRUT,ASPSST,DAYINC/
     1     0.0,1.0,14*0.0,7*25.8,0.0/
      DATA HFTIME,TIMELF/5.4,10.8/
      DATA ISTEM,NODE,XLEAFN,SIZELF,WTLEAF,WTINOD,WTPET,AREALF,
     1     WGHTLF,WTSTEM,XNLEAF,WTROOT,ICOUNT,PDAY,AGRPTS/2450*0,
     2     2450*0,7*0.0,1400*0.0,2800*0.0,1400*0.0,21*0.0,1407*0.0,
     3     2450*0,207*0.0/
      DATA STM42,WTLFM2,GRPTSM,XNOLFM,TOTM2,PENUTM,FRUITM,HSTPDM,
     1     HSTFRM,PEGSM2,ROTPM2,PNRIPM,BLOOMM,XLAI,IDAY/2601*0.0,
     2     200*0/
      DATA DAYADD/0.0/
      DATA IMERGE/7*-100/
      DATA PENUTZ,FRUIT,HSTPOD,HSTFRT,PEGS,R,FNRIPE,PETWT/56*0.0/
      DATA XMATUR/140./
      DATA PLTLAI,PTS/2*0.0/
      DATA PN/200*0.0/
      DATA STLFRT/0.0/
      DATA ASPGEN,PHZDAY/207*0.0/
      DATA WANTLF,NUMBR,XINODE/7*0.0,7*0,1400*0.0/
      DATA PODWGT,MORE,BLOOMZ,KPEGST,PEGNO,PODST,PODCAP,AGEMAX,GRATEK,
     1     KPODST,PQPODS,PQNUTS,PODAGE/1400*0.0,0,1400*0.0,0,1400*0.0,
     2     7*0.0,2800*0.0,22.0,0,14*0.0,200*0.0/
      DATA STMMIN,STMLOS/7*0.0,7*0.0/
      DATA XNONOD,NCOUNT,SURFAC/7*0.0,200*0,1400*0.0/
      DATA WGTBNZ,PTSS/1401*0.0/
      DATA LCOUNT/2450*0/
      DATA ROOTM2/200*0.0/
      DATA NEWVEG/1400*0/
      DATA XLIMT/7*0.0/
      DATA ROOTF,SMAINF/0.68,0.43/
      DATA MERGE/1/
      DATA PORT/1.0,6*0.0/
      DATA PODLM/0.0/
      DATA XLMMAZ/0.0/
      DATA EFFLAI/200*0.0/
      DATA AMTLT/200*0.0/
      DATA NDEX6/0/
      DATA NDEX9/0/
      DATA STORE/200*0.0/
      DATA NTYPE/2/
      DATA CONDEF/1.0/
      DATA CONGRO/0.0/
      END
```

APPENDIX 4
DESCRIPTION OF MODEL PARAMETERS

Parameter	Description	Numerical Value(s)*	Source
ADDLF	Amount of carbohydrate necessary for maximum growth each physiological day by a growing leaf and its attendant petiole and internode, mg	12.0 p.t. ≤ 82 9.0 p.t. > 82	Table 3
ADDSTM	Amount of carbohydrate necessary for maximum growth of a developing stem internode each physiological day after the attached leaf has ceased growing, mg	2.55	field results
AGEMAX(J,I)	Number of physiological days a developing peanut initiated on day I on plant J has to complete shell expansion--growth ceases is shell is not fully expanded at end of this time period	42	calibration, field results
ASPPRO	Conversion factor for asparagine to protein in the seeds	0.863	Duncan (1974 and personal communication)
ASVEGF	Conversion factor for asparagine to protein in the vegetative portion of the plant	0.786	Duncan (1974 and personal communication)
BMETFC	Maintenance respiration coefficient	0.01	Duncan (1974 and personal communication)
CONS1	Number of physiological days between flower and beginning of pod expansion at a reproductive node	27.0	calibration, field results

Parameter	Description	Numerical Value(s)*	Source
DAYDEG	Number of ^{o}F in a physiological day	25.0	Duncan (1974 & pers. comm.)
DECRTE	Coefficient for linear decline in canopy photosynthesis after day 119	0.33	Jones et al. (1980)
GRATEK	Maximum potential growth rate for kernels in 1 pod, mg/physiological day	22.0	Duncan (1974 & pers. comm.)
HFTIME	Number of physiological days for a leaf to be half-grown	5.4 p.t. $\leq$ 82 7.2 p.t $\geq$ 82	Table 6
HSTCPY	Ratio of photosynthetic efficiency of canopy at maximum to efficiency at harvest	0.30	Jones et al. (1980)
OILFAC	Ratio of weight of oil + carbohydrate in seed to weight of carbohydrate necessary to produce it	0.43	Duncan (1974 & pers. comm.)
PARFAC	Proportion of maximum 5-day-average of photosynthate which may go to seeds	0.65	calibration, field results
PCTC	Proportion of seed weight which is oil or carbohydrate	0.70	Duncan (1974 & pers. comm.)
PCTN	Proportion of seed weight which is nitrogen	0.25	Duncan (1974 & pers. comm.)
PNTCNR	Ratio of carbohydrate + oil to nitrogen in seeds	0.36	Duncan (1974 & pers. comm.)

Parameter	Description	Numerical Value(s)*	Source
PNTNCR	Ratio of nitrogen to carbohydrate + oil in seeds	2.80	Duncan (1974 & pers. comm.)
PNTOIL	Percent oil in seed	50.0	Duncan (1974 & pers. comm.)
PNTPRO	Percent protein in seed	25.0	Duncan (1974 & pers. comm.)
PODC	Percent carbohydrate in pod shell	0.85	Duncan (1974 & pers. comm.)
PODMAX	Maximum pod size, mg	1350	calibration, field results
PODN	Proportion of shell which is nitrogen	0.12	Duncan (1974 & pers. comm.)
PORLF	Maximum amount of weight a growing leaf can add each physiological day, mg	7.96 p.t. $\leq$ 82 5.98 p.t. $\geq$ 82	field results
PORNOD	Maximum amount of weight a growing internode can add each physiological day, mg	2.91 p.t. $\leq$ 82 2.18 p.t. $\geq$ 82	field results
PORPT	Maximum amount of weight a growing petiole can add each physiological day, mg	2.79 p.t. $\leq$ 82 2.10 p.t. $\geq$ 82	field results

Parameter	Description	Numerical Value(s)*	Source
PRIFAC	Priority factor for assignment of available photosynthate to expanding pods (0.0 = complete priority to older pods, 1.0 = each pod receives equal percentage of its demands)	0.0	Duncan (1974 & pers. comm.
PSLOPE	Slope of the photosynthetic equation, g/langley	0.0836	Duncan (1974 & pers. comm.)
PTSFAC	Factor related to photosynthetic efficiency of different cultivars	1.10	Duncan (1974 & pers. comm.)
REPTIM	Number of physiological days between nodes on a reproductive branch	6.0	field results
RESPFC	Growth respiration factor	0.30	Duncan (1974 & pers. comm.)
ROOTF	Proportion of photosynthate allocated to roots which is used for root growth and maintenance respiration	0.68 p.t. $\leq$ 34 0.43 34 < p.t. $\leq$ 60 0.01 p.t. > 60	calibration, field results
SETMIN	Temperature below which development does not occur, ^{o}F	50.0	Duncan (1974 & pers. comm.)
SIZMIN	If leaf completing development after day 82 weighs less than this amount, growing points are inactivated, mg	70.0	calibration, field results

Parameter	Description	Numerical Value(s)*	Source
SIZRED	Slope of line for decrease in pod capacity with day of initiation	0.013	Duncan (1974 & pers. comm.)
SLW	Specific leaf weight for new leaves, mg/cm^2	4.98 p.t. $\leq$ 40 3.77 40 < p.t. $\leq$ 82 3.28 p.t. > 82	Table 3
SMAINF	Proportion of net photosynthate allocated to roots	0.43 p.t. $\leq$ 34 0.30 34 < p.t. $\leq$ 60 0.15 p.t. > 60	calibration, field results
STDECL	Days from planting until photosynthetic efficiency of canopy begins to decline	119	Jones et al. (1980)
TIMELF	Physiological days for a leaf to complete development	10.8 p.t. $\leq$ 82 14.4 p.t. > 82	Table 6
TMPOPT	Temperature above which the rate of development does not increase, ^{o}F	90.0	Duncan (1974 & pers. comm.)
VEGCNR	Ratio of carbohydrate to nitrogen in the vegetative portion of the plant	7.1	Duncan (1974 & pers. comm.)
VEGNCR	Ratio of nitrogen to carbohydrate in the vegetative portion of the plant	0.14	Duncan (1974 & pers. comm.)
VEGPRO	Percent protein in the vegetative portion of the plant	12.0	Duncan (1974 & pers. comm.)

* p.t. stands for physiological time in days from planting

APPENDIX 5
INPUT PARAMETERS AND
VARIABLES DESCRIBING THE DYNAMICS OF
PEANUT PLANT GROWTH

Input Parameters

CLIMAT(I,1) - total radiation on day I in langleys

CLIMAT(I,2) - maximum temperature on day I, to the nearest ^{o}F

CLIMAT(I,3) - minimum temperature on day I, to the nearest ^{o}F

CLIMAT(I,4) - rainfall and irrigation on day I, 0.01 in

CLIMAT(I,5) - not used

CLIMAT(I,6) - Julian day

CONDEF - proportion of leaf matter left after defoliation (1.0 - portion defoliated)

CONGRO - proportion of active vegetative meristems destroyed by an insect attack

DEFTIM - number of days from planting until defoliation begins

EMERGE - number of physiological days from planting until plants start to emerge

NTYPE - an indicator of type of defoliation (1 = uniform throughout the canopy, only fully developed leaves; 2 = outer portion of canopy; 3 = uniform + partially formed leaves + vegetative meristems)

PLTDAY - Julian day of planting

PLTPOP - number of plants/m^2

PROPOR(J) - number of plants/m^2 which emerge on day J

PORT(J) - proportion of plants which emerge on day J

ROWMID - distance between rows, cm

ROWSPC - distance between plants within a row, cm

TMETRC - indicator for metric weather data (if it equals 1.0, data is metric, otherwise it is not)

TTL - a title for the simulation run

XMATUR - number of calendar days from planting until harvesting

Variables Describing the Dynamics of Peanut Plant Growth

ADDRAT(J) - ratio of photosynthate available to a developing leaf on plant J from the daily photosynthate pool to the amount necessary for maximum potential growth

ADD2(J) - proportion of the demand for photosynthate by a leaf that is more than half-grown that is filled from stem storage on plant J

AGELAR(J) - age of larvae feeding on plant J

AGRPTS(J) - number of active vegetative growing points on plant J

AMTLT(I) - percent of available light intercepted by the canopy on day I

AREALF(J) - leaf area of plant J

ASPGEN(J) - amount of nitrogen (asparagine) manufactured each day by plant J

ASPGST(J) - amount of nitrogen (asparagine) available for growth each day by plant J

ASPREQ - amount of nitrogen (asparagine) required for a certain amount of growth

AVLCON(J) - ratio of amount of carbohydrate available for growth of various plant parts on plant J to amount needed for maximum growth on a given day

BLOOMM(I) - number of flowers per m^2 on day I

BLOOMZ(J,I) - number of flowers on plant J on day I

CONSUM - leaf area consumed by larvae on a given day, cm^2/m^2

DAYADD - change in LAI from one day to the next

DAYINC - number of physiological days in one calenday day (computed each day)

DECFCT - ratio of photosynthetic efficiency of aging canopy to maximum efficiency

EFFLAI(I) - effective leaf area index on day I

FRUCHO - amount of carbohydrate used in seed and shell growth on a given day, mg

FRUIT(J) - weight of peanuts on plant J, g

FRUITM(I) - weight of peanuts in g/m^2 on day I

FRUNIT - amount of nitrogen allocated to seeds and shells on a given day, mg

GRPTSM(I) - number of active vegetative growing points/m^2 on day I

GRRATE - amount added to each growing peanut in mg on a calendar day

HSTFRM(I) - weight of fruit that are filling seeds on day I, g/m^2

HSTFRT(J) - weight of fruit that are filling seeds on plant J on a given day, g

HSTPDM(I) - number of fruit that are filling seeds per m^2 on day I

HSTPOD(J) - number of fruit that are filling seeds on plant J on a given day

ICOUNT(J,K) - day of initiation of the most recent leaf on plant J, stem K, starting from beginning of simulation

IDAY(I) - day from planting on day I

IMERGE(J) - date of emergence of plant J

INIT - day plants start emerging

ISTEM(J,K) - type of stem K on plant J (1 = mainstem, 2 = cotyledonary lateral, 3 = one of first 4 laterals off the mainstem, 4 = other vegetative branch, 5 = reproductive branch, 6 = branch that has stopped growing)

J - index for plants that emerged on same day (from 1 - 7)

KPEGST - date flowering starts

KPODST - date pods start to form

LCOUNT(J,K) - date of initiation of the next-to-the-last leaf on plant J, stem K

MERGE - number of days on which plants emerge

MORE - not used at this time

MORROW - current simulation day + 1, counting from start of the simulation

NCOUNT(I) - date leaves initiated on day I completed development

NDEX1 - an indicator of ELAI (0 = less than 0.161, 2 = less than 2.0, 3 = less than 2.5, 4 = greater than 2.5)

NDEX2 - an indicator that enough physiological days have passed that plants can start emerging

NDEX3 - an indicator that the pod load has been set

NDEX5 - an indicator that a given ELAI has been surpassed at least one time

NDEX6 - an indicator of whether GRPTS should be called to initiate new vegetative branches on a given day

NDEX9 - an indicator of whether vegetative growing points may be inactivated

NEWREP(J,I) - number of potentially active reproductive nodes on plant J which were added to plant on day I--not used at present

NEWVEG(J,I) - number of potentially active vegetative nodes on plant J which were added to plant on day I

NODE(J,K) - number of nodes on stem K of plant J

NOW - integer equivalent of TNOW

NUMBR(J) - number of vegetative and reproductive branches on plant J

PDAY(I) - physiological days from day I (only non-zero when there are growing leaves initiated on day I)

PEANUT - amount of carbohydrate available for fruit growth on a given day

PEGDED(J) - number of days there has been no photosynthate available to fill demand from expanding pods on plant J

PEGNO(J,I) - number of peanuts on plant J initiated on day I

PEGS(J) - total number of pegs on plant J on a given day

PEGSM2(I) - number of pegs per m^2 on day I

PENUTM(I) - number of peanuts per m^2 on day I

PENUTZ(J) - number of peanuts on plant J on a given day

PETWT(J) - weight of petioles on plant J on a given day

PHZDAY(I) - physiological days since day I (used for turning flowers into peanuts)

PN(I) - net photosynthesis on day I, g/m^2

PNRIPE(J) - weight of ripe peanuts on plant J on a given day

PNRIPM(I) - maximum weight of ripe peanuts per m^2 up until day I

PNTCHO - amount of carbohydrate used in seed growth on a given day, mg

PODCHO - total amount of carbohydrate required by shells for maximum growth on a given day, mg

PODAGE(I) - physiological age of pods initiated on day I

PODCAP(J,I) - pod capacity for peanuts initiated on day I on plant J

PODLM - maximum five-day-average net photosynthate

PODST(J) - date of pod initiation on plant J

PODWGT(J,I) - weight of an individual peanut initiated on day I on plant J

PQNUTS(J) - total amount of weight developing nuts require for maximum growth on a given day on plant J

PQPODS(J) - total amount of weight developing pods require for maximum growth on a given day on plant J

PTS - net photosynthesis in g/m^2 each day

PTSRUT(J) - amount of daily photosynthate which goes to roots of plant J, in mg

PTSYN(J) - amount of daily photosynthate which goes to plant J, in mg

PTSS - used to carry leftover carbohydrate from FRUFIL to DIVIDE

R(J) - weight of fruit lost from plant J due to pegs rotting

RATIO - ratio of carbohydrate available to developing shells to amount necessary for maximum growth

ROOTM2(I) - weight of roots in g/m^2 on day I

ROTPM2 - weight of pods lost per m^2 due to pegs rotting

SIZELF(J,I) - weight of leaves initiated on day I on plant J (total)

SS(1) - effective leaf area index

SS(2) - physiological day since planting date

SS(3) - real leaf area index

STLFRT - weight of stems, leaves, and petioles, in g/m^2

STMLOS(J) - not used at present

STMMIN(J) - amount of carbohydrate in stem storage for plant J, mg

STMM2(I) - weight of stems on day I, g/m^2

STRESF - water stress factor

SUMLAR(J) - number of larvae feeding on plant J

SURFAC(J,I) - leaf area of fully developed leaves on plant J initiated on day I

TNOW - current simulation day, counting from start of simulation

TOTEAT - total amount of foliage consumed by insects attacking the crop, cm^2/m^2

TOTM2(I) - total plant weight in g/m^2 on day I

WANTBG(J) - amount of carbohydrate needed for maximum growth by leaves developing on plant J which are more than half-grown on a given day, mg

WANTLF(J) - amount of carbohydrate necessary for maximum growth of leaves developing on plant J on a given day, mg

WGHTLF(J) - weight of leaves on plant J, g

WGTBNZ(J,I) - weight of peanuts on plant J initiated on day I, mg

WNTNUT(J) - amount of carbohydrate needed by seeds on plant J for maximum growth on a given day, mg

WNTPOD(J) - amount of carbohydrate needed by expanding pods on plant J for maximum growth on a given day, mg

WNTSTM(J) - amount of carbohydrate needed by developing stem internodes on plant J for maximum growth on a given day, mg

WNTSTO(J) - amount of carbohydrate "wanted" by stems for storage on plant J on a given day--always zero at present

WTINOD(J,I) - weight in mg of an individual internode initiated on day I on plant J

WTLEAF(J,I) - weight in mg of an individual leaf initiated on day I on plant J

WTLFM2(I) - weight of leaves in g/m^2 on day I

WTPET(J,I) - total weight in mg of all petioles initiated on day I on plant J

WTROOT(J) - weight of roots on plant J, g

WTSTEM(J) - weight of stems on plant J, g

XINODE(J,I) - number of internodes on plant J initiated on day I

XLAI(I) - leaf area index on day I

XLEAFN(J) - number of leaves on plant J on a given day

XLIMT(J) - proportion of day's photosynthate which may be used by plant J for seed development

XLMMAZ - maximum average of 5 days' photosynthate

XNLEAF(J,I) - number of leaves on plant J which were initiated on day I

XNOLFM(I) - number of leaves per m^2 on day I

XNONOD(J) - number of internodes on plant J on a given day

REFERENCES CITED

Arthur, B.W., L.L. Hyche, and R.H. Mount. 1959. Control of the red-necked peanutworm on peanuts. J. Econ. Entomol. 52: 468-70.

Bhagsari, A.S., and R.H. Brown. 1973. Photosynthesis in peanut genotypes. Amer. Peanut Res. Ed. Assoc. J. 5: 194.

Bhagsari, A.S., and R.H. Brown. 1976. Photosynthesis in peanut (Arachis) genotypes. Peanut Sci. 3: 1-5.

Bolhuis, G.G. 1958. Observations on the flowering and fructification of the groundnut, Arachis hypogaea L. II. Neth. J. Agric. Sci. 6: 245-8.

Bolhuis, G.G., and W. DeGroot. 1959. Observations on the effect of varying temperatures on the flowering and fruit set in three varieties of groundnut. Neth. J. Agric. Sci. 7: 317-26.

Cahaner, A., and A. Ashri. 1974. Vegetative and reproductive development of Virginia-type peanut varieties in different stand densities. Crop Sci. 14: 412-6.

Cox, F.R. 1978. Effect of quantity of light on the early growth and development of the peanut. Peanut Sci. 5: 27-30.

Cox, F.R. 1979. Effect of temperature treatment on peanut vegetative and fruit growth. Peanut Sci. 6: 14-7.

Duncan, W.G. 1974. PENUTZ, a simulation model for predicting growth, development, and yield of a peanut plant. Amer. Peanut Res. Ed. Assoc. Proc. 6: 72.

Duncan, W.G., D.E. McCloud, R.L. McGraw, and K.J. Boote. 1978. Physiological aspects of peanut yield improvement. Crop Sci. 18: 1015-20.

Enyi, B.A.C. 1975. Effects of defoliation on growth and yield in groundnut (Arachis hypogaea), cowpeas (Vigna unguiculata), soyabean (Glycine max) and green gram (Vigna aurens). Ann. Appl. Biol. 79: 55-66.

Fehr, W.R., C.E. Caviness, and J.J. Vorst. 1977. Response of indeterminate and determinate soybean cultivars to defoliation and half-plant cut-off. Crop Sci. 17: 913-7.

Gautreau, J. 1973. Influence of climatic factors on the growth and development of early groundnut. (French). Oleagineux 28: 567-77.

Greene, G.L., and D.W. Gorbet. 1973. Peanut yields following defoliation to assimilate insect damage. J. Amer. Peanut Res. Ed. Assoc. 5: 141-2.

Gregory, W.C., B.W. Smith, and H.A. Yarbrough. 1951. Morphology, genetics and breeding. p. 28-88. In The Peanut--The Unpredictable Legume. Nat. Fert. Assoc., Washington, D.C.

Gupton, C.L., D.A. Emery, and J.A. Benson. 1968. Reproductive efficiency of Virginia type peanuts. III. Relating the time of peg placement to the branching pattern of the plant. Oleagineux 23: 247-50.

Hackett, C. 1972. An exploration of the carbon economy of the tobacco plant. I. Inferences from a simulation. Aust. J. Biol. Sci. 26: 1057-71.

Hang Ngoc An. 1976. Low light intensity at different stages of growth as affecting peanut yield components. M.S. thesis, Univ. Fla. 76 pp.

Hang Ngoc An. 1978. Light intensity effects on metabolism, growth, and yield components of peanuts. Ph.D. Dissertation, Univ. Fla. 119 pp.

Henning, R.J., R.H. Brown, and D.A. Ashley. 1979. Effects of leaf position and plant age on photosynthesis and translocation in peanut. I. Apparent photosynthesis and ^{14}C translocation. Peanut Sci. 6: 46-50.

Huffman, F.R. 1974. Consumption of peanut foliage by the bollworm, *Heliothis zea* (Boddie) (Lepidoptera:Noctuidae). M.S. thesis, Texas A & M Univ. 40 pp.

Jacobs, W.P. 1951. The growth of peanut plants at various diurnal and nocturnal temperatures. Sci. 114: 205-6.

Jones, J.W., C.S. Barfield, K.J. Boote, G.H. Smerage, and J. Mangold. 1980. Photosynthetic recovery of peanuts to defoliation at various growth stages. Crop Sci. (in review).

Jones, J.W., L.G. Brown, J.D. Hesketh. 1980. COTCROP: A simulation of cotton growth and yield. p. 209-41. In Predicting Photosynthesis for Ecosystem Models, Vol. II. CRC Press, Inc., Boca Raton, Fla.

Jones, J.W., and G.H. Smerage. 1978. Representation of plant/crop physiology. ASAE Tech. Paper No. 78-4024. 11 pp.

Linker, H.M. 1980. An analysis of seasonal abundance and sampling procedures for the major defoliating Lepidoptera in peanuts and soybeans in north Florida. Ph.D. Dissertation, Univ. Fla. 183 pp.

Malagamba, J.P. 1976. Plant density relationships in peanuts (Arachis hypogaea L.) Ph.D. Dissertation, Univ. Fla. 104 pp.

Mangold, J. 1979. Seasonal abundance of defoliating lepidopterous larvae and predaceous arthropods and simulated defoliator damage to peanuts. Ph.D. Dissertation, Univ. Fla. 109 pp.

McCloud, D.E. 1974. Growth analysis of high yielding peanuts. Soil Crop Sci. Soc. Fla. Proc. 33: 24-6.

McGill, J.F. 1973. Economic importance of peanuts. pp. 3-15. In Peanuts--Culture and Uses. Amer. Peanut Res. Ed. Assoc. Oklahoma State Univ., Stillwater, Oklahoma.

McGraw, R.L. 1977. Yield dynamics of Florunner peanuts (Arachis hypogaea L.) M.S. thesis, Univ. Fla. 37 pp.

McKinion, J.M., D.N. Baker, J.D. Hesketh, and J.W. Jones. 1975. SIMCOT II: A simulation of cotton growth and yield. p. In Computer Simulation of a Cotton Production System--User's Manual. ARS-S-52, New Orleans, La.

Morgan, L.W. 1979. Economic thresholds of Heliothis species in peanuts. p. 71-4. In Economic Thresholds and Sampling of Heliothis Species on Cotton, Corn, and Other Host Plants. Southern Cooperative Series Bull. No. 231. 159 pp.

Nickle, D.A. 1977. The peanut agroecosystem in central Florida: Economic thresholds for defoliating noctuids (Lepidoptera, Noctuidae); associated parasites; hyperparasitism of the Apanteles complex (Hymenoptera, Braconidae). Ph.D. Dissertation, Univ. Fla. 131 pp.

Pallas, J.E., Jr., and Y.B. Samish. 1974. Photosynthetic response of peanut. Crop Sci. 14: 478-81.

Pritsker, A.A. 1974. The GASP IV Simulation Language. John Wiley & Sons, New York. 451 pp.

Ritchie, J.T. 1972. Model for predicting evaporation from a row crop with incomplete cover. Water Resources Res. 8: 1204-1213.

Rudd, W.G., W.G. Ruesink, L.D. Newson, D.C. Herzog, R.L. Jensen, and N.F. Marsolan. 1980. The systems approach to research and decision-making for soybean pest control. In New Technology of Pest Control (C.B. Huffaker, Ed.). John Wiley & Sons, Inc., New York (in press).

Schenk, R.U. 1961. Development of the peanut fruit. Georgia Agric. Exp. Stn. Tech. Bull. N. S. 22.

Smith, B.W. 1954. Arachis hypogaea reproductive efficiency. Amer. J. Bot. 41: 607-16.

Smith, J.W., Jr., and P.W. Jackson. 1974. Research on the economic thresholds of peanut insects. Ann. Prog. Report, Texas A & M Univ., unpublished.

Smith, J.W., Jr., and D.G. Kostka. 1975. Modeling foliage consuming lepidoptera on peanuts. Proc. Amer. Peanut Res. Ed. Assoc. 7: 66.

Stapleton, H.N., and R.P. Meyers. 1971. Modeling subsystems for cotton--the cotton plant simulation. Trans. ASAE 14: 950-3.

Trachtenberg, C.H. 1976. Net photosynthesis of peanut leaves at varying light intensities and leaf ages. M.S. thesis, Univ. Fla. 36 pp.

Williams, J.H., J.H.H. Wilson, and G.C. Bate. 1975. The growth and development of four groundnut (Arachis hypogaea L.) cultivars in Rhodesia. Rhod. J. Agric. Res. 13:131-44.

Williams, J.H., J.H.H. Wilson , and G.C. Bate. 1976. The influence of defoliation and pod removal on growth and dry matter distribution in groundnuts (Arachis hypogaea L. cv. Makulu Red). Rhod. J. Agric. Res. 14: 111-7.

Wynne, J.C. 1975. Inheritance of branching pattern in Arachis hypogaea L. Peanut Sci. 2: 1-5.

Young, J.H., F.R. Cox, and C.K. Martin. 1979. A peanut growth and development model. Peanut Sci. 6: 27-36.

BIOGRAPHICAL SKETCH

Gail Ellen Geier Wilkerson was born on 12 November 1946 in Nashville, Tennessee. She attended public schools in Nashville until graduation from John Overton High School in 1964. She then entered Duke University in Durham, North Carolina, and received a B. S. degree in mathematics in 1968.

In 1967 she and Richard Wilkerson were married. She received a National Science Foundation Traineeship and began graduate studies in mathematics at the University of Florida in the fall of 1968. Upon the induction of her husband into the U. S. Army in the summer of 1969, she moved to San Antonio, Texas, where she worked as a technical secretary and teacher until 1972. She then returned to Gainesville to pursue graduate studies in entomology, and she received her Master of Science degree in 1974.

She then moved to Cali, Colombia, and worked as a computer programmer for the International Center for Medical Research until the summer of 1976, when she again returned to Gainesville to begin work toward the degree of Doctor of Philosophy in the Department of Entomology and Nematology, University of Florida, under the auspices of a CSRS pest management grant. She had a son, Trevor Alan, in November 1976. Her marriage ended in divorce in 1978.

Gail Wilkerson is a member of the Phi Kappa Phi Honor Society.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

S. H. Kerr
S. H. Kerr, Chairman
Professor of Entomology and Nematology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Tom R. Ashley
T. R. Ashley
Assistant Professor of Entomology and Nematology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

J. W. Jones
J. W. Jones
Associate Professor of Agricultural Engineering

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

R. C. Littell
Associate Professor of Statistics

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and the the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June 1980

Jack L. Fry

Dean, College of Agriculture

Dean, Graduate School